REPORT NUMBER FC-2094

(4)

COLLAPSIBLE FABRIC TANK TESTING

FINAL TECHNICAL REPORT

BY DON V. PERKINS

UNIROYAL PLASTICS COMPANY, INC.
ENGINEERED SYSTEMS DIVISION

SEPTEMBER 29, 1989

CONTRACT NUMBER DAAK70-87-C-0078

UNITED STATES ARMY
BELVOIR RESEARCH AND DEVELOPMENT ENGINEERING CENTER
FORT BELVOIR, VIRGINIA

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle) Collapsible Fabric Tank Testing	5. TYPE OF REPORT & PERIOD COVERED Final Technical Report October 1987 - Sept. 1989
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Don V. Perkins	8. CONTRACT OR GRANT NUMBER(s) DAAK-70-87-C-0078
9. PERFORMING ORGANIZATION NAME AND ADDRESS Engineered Systems Division Uniroyal Plastics Company, Inc. Mishawaka, IN 46544	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Belvoir R & D Center Fort Belvoir, VA 22060	12. REPORT DATE September 29, 1989
	13. NUMBER OF PAGES
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report) Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Tank, Fabric, Collapsible, Fuel, Water, Weathering, Use Life, Abrasion EG

20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Was conducted

Uniroyal Plastics Company, Inc. conducted a test program on military fuel and water static storage tanks which involved the following: (1) Weatherometer aging of government supplied tanks to 2000 hours, (2) Fuel testing of tank materials for 14, 28 and 42 days in Fuel B and MIL-F-46162B + EGME @ 160°F, (3) Three different types of abrasion testing, (4) Development of non-destructive test methods to predict tank serviceability and remaining service life, (5) Analysis of packaging and handling of tanks with recommendations for increasing storage and service life

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1.0 SUMMARY

Uniroyal Plastics Company, Inc. performed tests on government tank material, as specified in this contract. These tests were:

1. Tensile elongation and tear properties after 2000 hours weatherometer aging.
2. Seam peel/shear adhesions and fitting shear adhesion testing on tank samples after exposure to Fuel B and MIL-F-46162B fuel containing EGME @ 160°F for exposure periods of 14, 28 and 42 days.

This data is to be used to provide updated data for specification requirements which will reflect state-of-the-art commercial products.

Part of this effort included a test program to test tank abrasion resistance according to three different test methods and relate this to relative field performance. Data under this section was accumulated for two of the three test methods. This section was terminated due to the government's inability to provide relative field performance data for the tank types tested (a criteria of the program).

The remaining work performed under this contract was geared towards developing non-destructive test methods which can be used to predict storage tank serviceability and projected use life. The results of this effort have produced a method for checking a storage tank's serviceability by measuring the tank's ability to sustain a load across its seams and body panels through the use of a Uniroyal developed "clamp-on" test fixture. This fixture is affixed to the tank in several locations and a load applied which represents the tank's stress loading when filled to capacity, plus whatever safety factor may be deemed appropriate. A tank passing this applied load test can be placed in service with a reasonable degree of confidence as to its serviceability.

A method for assessing serviceability and predicted service life was also developed for Uniroyal polyurethane fuel storage tanks. This method involves the measurement of the tank wall's elongation at a given load using the "clamp-on" test fixture and relating this to charts plotting elongation and tear vs tank age which were also developed during this contract effort.

A non-destructive method for predicting serviceability of Uniroyal supplied chlorobutyl water tanks was developed which involves the sampling of a small amount of tank coating compound which is subjected to a carbon/oxygen ratio test. This test result is then compared to a chart developed from the testing of carbon/oxygen ratios on Uniroyal tanks of various ages. A test result obtained, which falls within the developed plot, indicates the tank's serviceability.

A study was done under this contract to assess the current packaging and handling techniques associated with military fuel and water storage tanks. The focus of this study was to make recommendations which, if implemented, would improve a tank's storage and service life.

2.0 INTRODUCTION

2.1 This final report is submitted for the work performed under Contract DAAK70-87-C-0078. This contract to the U.S. Army was undertaken to define test methods and perform prescribed testing on government furnished petroleum and water tanks. The goals of this program were:

1. Provide updated performance characteristic testing to enable specifications to be updated to reflect state-of-the-art commercial products. Specific areas evaluated were:

   a. Weatherometer aging
   b. Referee diesel lading tests
   c. Abrasion testing methods

2. Establish non-destructive test methods which can predict remaining reliable service life within +/- six months. Since this goal relates directly to the Army's tank life extension program, Uniroyal Plastics Company, Inc. included in its work effort an evaluation of tank design, packaging, handling and repackaging procedures. Recommendations from this evaluation, if implemented, will positively impact both the use life and storage life of state-of-the-art petroleum and water tanks.

3. The interpretation and use of the above mentioned testing would serve to extend the current assumed storage and use life of this line of products towards the eventual goal of five years service and twenty years storage.

3.0 TANKS UTILIZED FOR TEST PURPOSES

3.1 During the course of this contract, fourteen tanks were used in the program for data acquisition purposes. These tanks consisted of seven tanks supplied by the U.S. Government from warehouse stocks and seven tanks supplied by Uniroyal Plastics Company, Inc. The Uniroyal supplied tanks had been used for in-house testing purposes. A complete listing of these tanks is shown in Table I of this report.

TABLE I

TANKS UTILIZED FOR TEST PURPOSES

TANK	FUEL/ WATER	SIZE	MFGR	MFG DATE	GOVERNMENT CONTRACT	SUPPLIED BY
S/N W510	F	10K	Uniroyal	5/81	----	Uniroyal
S/N W358	F	42K	Uniroyal	7/84	----	Uniroyal
S/N W9	F	10K	Uniroyal	10/84	----	Uniroyal
S/N W1109	F	20K	Uniroyal	2/85	----	Uniroyal
S/N W155	F	10K	Uniroyal	11/85	DAAK01-85-D-B012	Government
S/N W158	F	10K	Uniroyal	11/85	DAAK01-85-D-B012	Government
S/N 794	F	10K	ILC	3/85	DAAJ09-82-C-D135	Government
S/N 6	W	10K	Uniroyal	5/77	----	Uniroyal
S/N W1	W	20K	Uniroyal	10/81	----	Uniroyal
S/N W150	W	50K	Uniroyal	3/83	DAAJ09-81-C-1785	Government
S/N W122	W	50K	Uniroyal	3/83	DAAJ09-81-C-1785	Government
S/N W2	W	10K	Uniroyal	7/84	----	Uniroyal
S/N 84-25727	W	20K	Goodyear	2/83	DAAK70-82-C-0126	Government
S/N 84-13805	W	20K	Goodyear	2/84	DAAK70-82-C-0126	Government

4.0 TASK I ACCELERATED WEATHERING TESTS

4.1 Uniroyal Plastics Company, Inc. ran weatherometer aging tests on samples of tank body wall material removed from the following government supplied tanks:

S/N W150	50K	Uniroyal	Water Tank
S/N 8425727	20K	Goodyear	Water Tank
S/N W155	10K	Uniroyal	Fuel Tank
S/N 794	10K	ILC	Fuel Tank

Sufficient material was weatherometer aged to obtain data points for warp and fill tensiles aged 0, 500, 1000, 1500 and 2000 hours. Sufficient samples were also aged to provide samples for testing tongue tear in the warp and fill directions for the same weatherometer aging periods.

The tensile testing was performed per Federal Standard 191, Method 5804. The warp and fill samples were elongated 5% during the weatherometer exposure periods.

The tongue tear testing was done per Federal Standard 191, Method 5134.

Fabric edges of the tensile specimens were protected from direct U.V. exposure by exposing a two-inch wide sample, then cutting it prior to actual pull testing. The tongue tear specimens were aged without the center starter cut made. This cut was made after aging.

The weatherometer agings were done in an Atlas carbon arc weatherometer, Model WX with alternate Corey D filters removed per Federal Standard 191, Method 5804.

Tensile and tear testing was performed on a Scott Model CRE test machine equipped with a 2000 pound load cell.

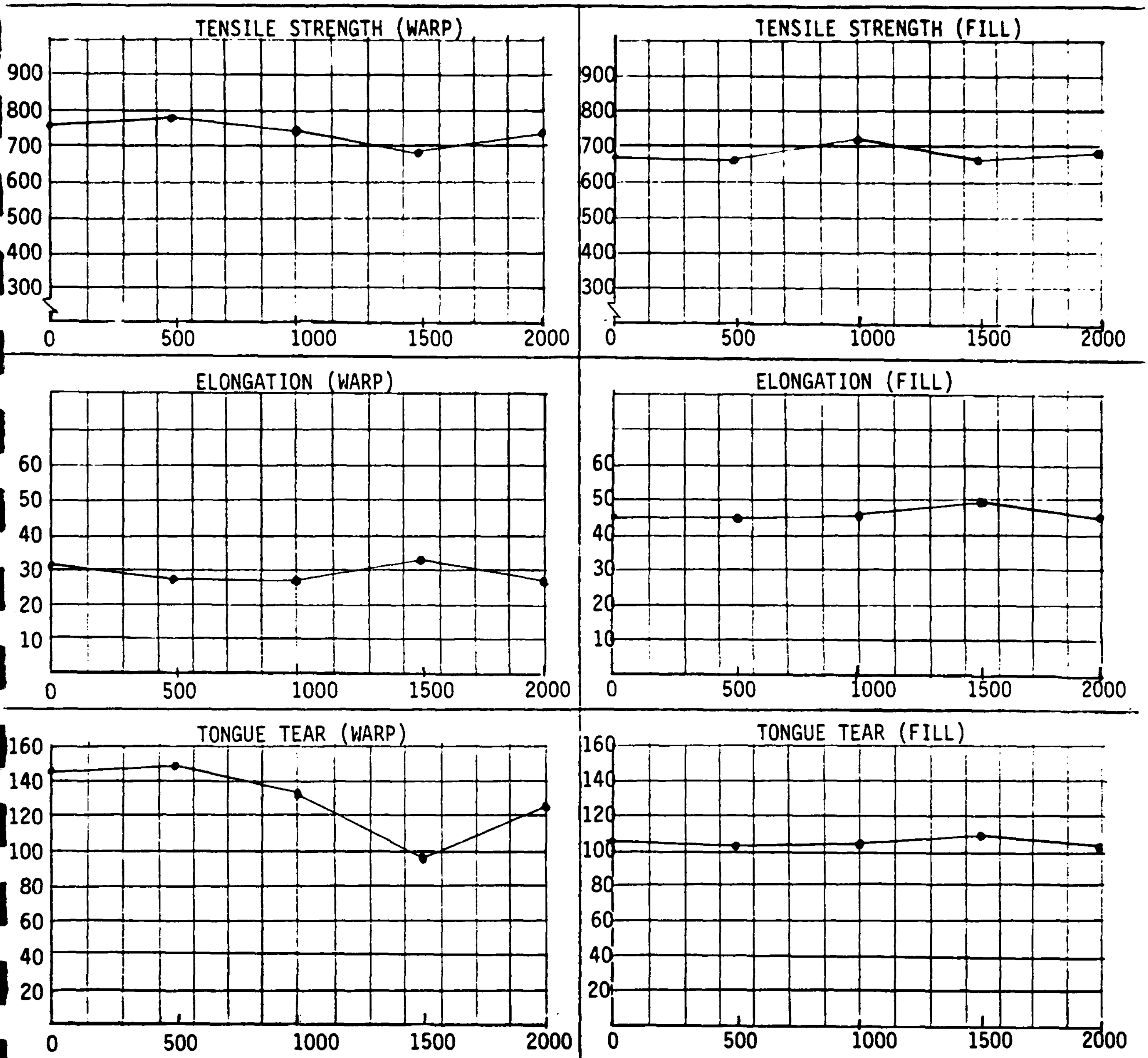
The data from this portion of the test program is presented in Tables II through VI of this report. Table II shows the data in tabular form and Tables III through VI present the data for each tank material tested in graph form.

TABLE II

WEATHEROMETER AGING TEST RESULTS

			0	500	1000	1500	2000	% Retention @ 2000 Hrs
S/N W150 Uniroyal 50K H_2O Tank	Tensile	W	770	798	750	675	735	95.4
		F	695	685	705	650	693	99.7
	Elong	W	31	28	28	33	28	90.0
		F	46	44	45	50	45	97.8
	Tongue Tear	W	146	150	135	97	125	85.6
		F	106	103	103	113	105	99.0
S/N 84-25727 Goodyear 20K H_2O Tank	Tensile	W	650	593	685	658	683	105.1
		F	630	530	558	520	470	71.4
	Elong	W	24	22	23	28	24	100.0
		F	48	43	45	49	48	100.0
	Tongue Tear	W	90	69	44	74	62	68.9
		F	58	56	66	55	48	82.8
S/N W155 Uniroyal 10K Fuel Tank	Tensile	W	800	783	798	735	890	111.0
		F	815	638	710	690	695	85.3
	Elong	W	31	28	27	33	30	96.8
		F	46	38	39	44	39	84.8
	Tongue Tear	W	106	102	99	69	78	73.6
		F	104	100	106	76	89	85.6
S/N 794 ILC Dover 10K Fuel Tank	Tensile	W	540	490	505	485	490	90.7
		F	465	495	473	290	283	60.9
	Elong	W	26	28	23	28	23	88.5
		F	35	29	34	35	32	91.4
	Tongue Tear	W	43	47	40	29	42	97.7
		F	46	42	35	30	35	76.1

TABLE III
WEATHEROMETER DATA
S/N W 150 50K WATER UNIROYAL



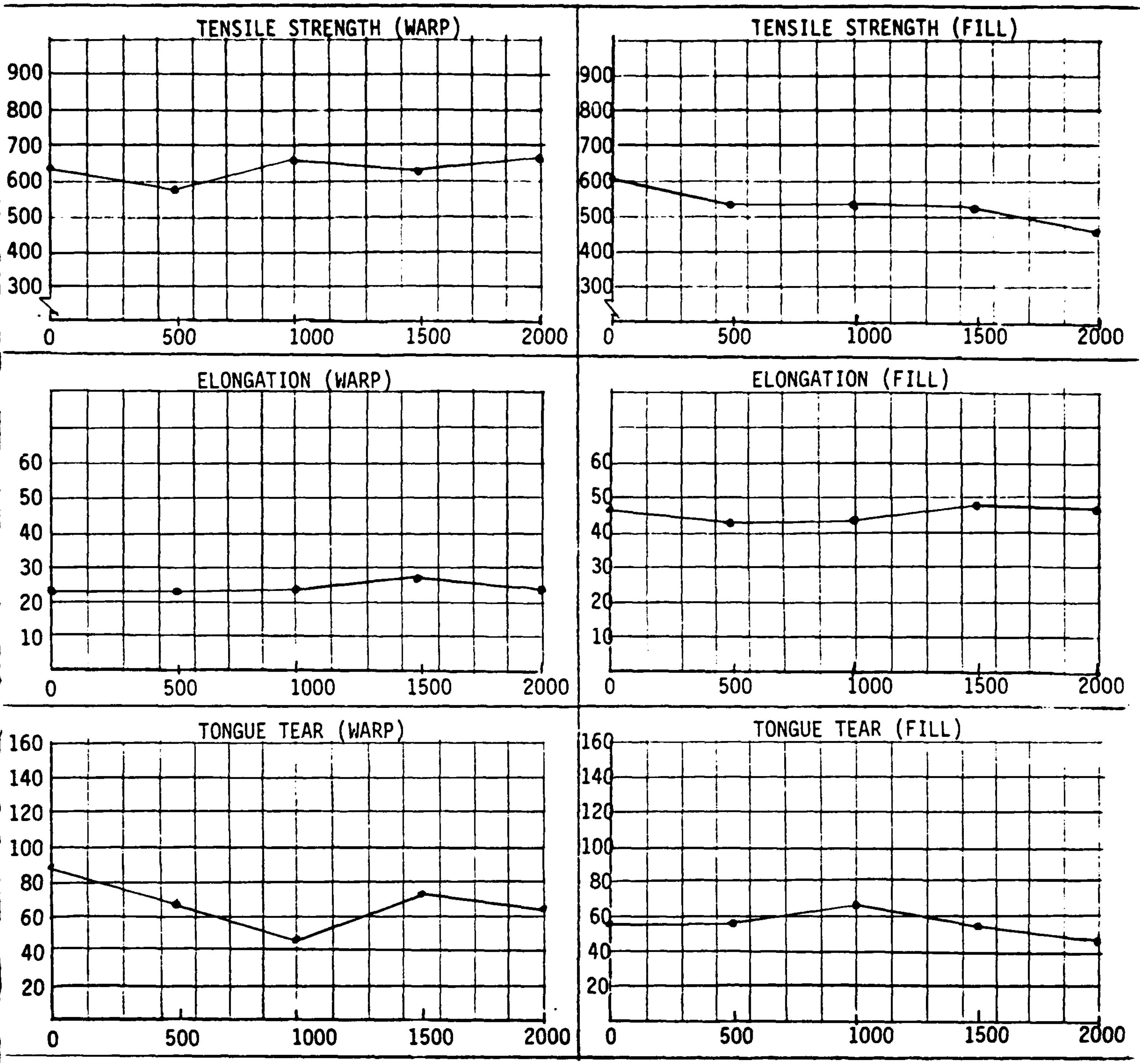
Tensile Strength - Fed Std 191 Method 5102
Elongation - Fed Std 191 Method 5102
Tongue Tear - Fed Std 191 Method 5134

X Axis - Weatherometer Aging in Hours
Y Axis - Properties as shown

TABLE IV

WEATHEROMETER DATA

S/N 84-25727 20K WATER GOODYEAR



Tensile Strength - Fed Std 191 Method 5102

Elongation - Fed Std 191 Method 5102

Tongue Tear - Fed Std 191 Method 5134

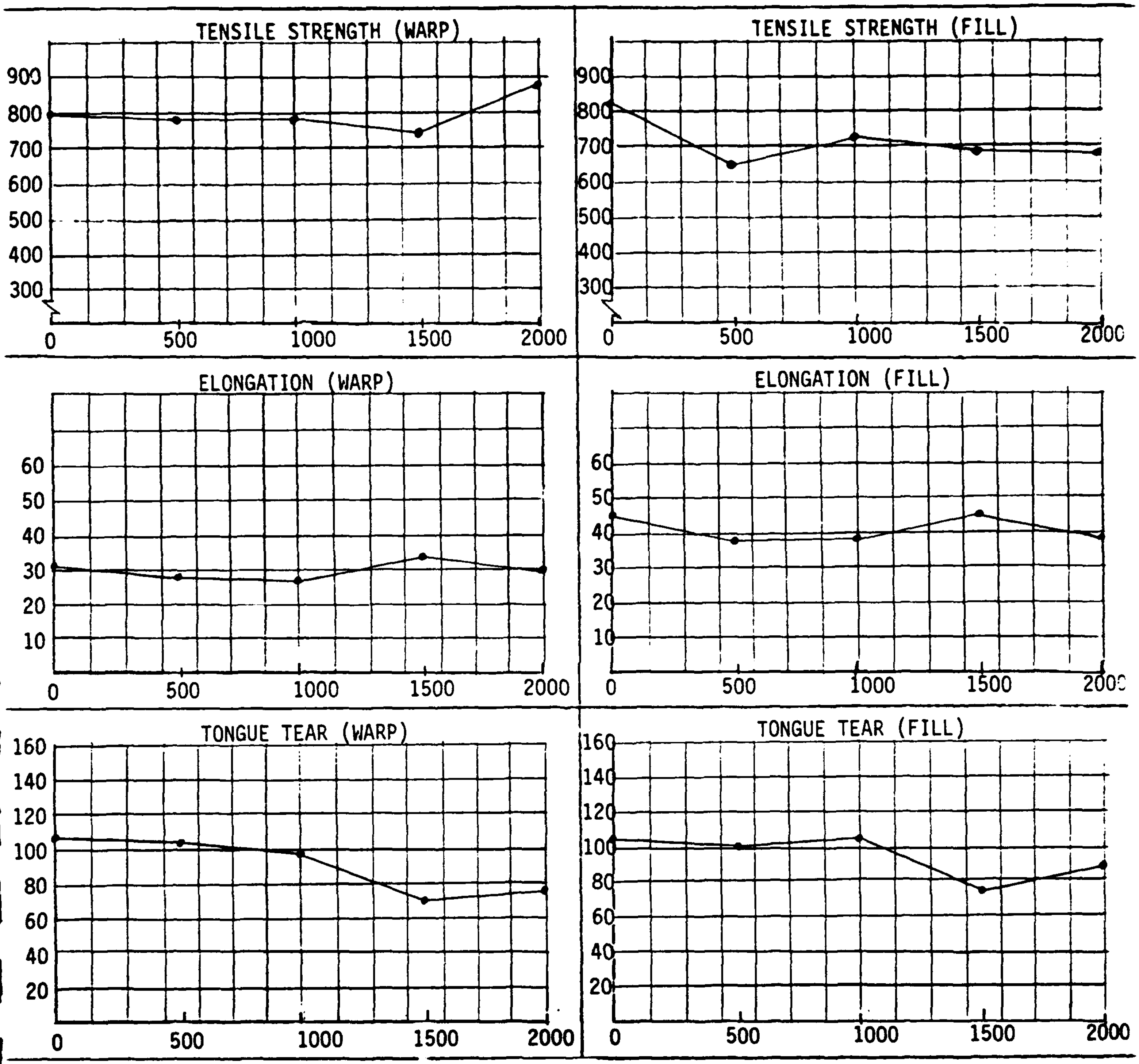
X Axis - Weatherometer Aging in Hours

Y Axis - Properties as shown

TABLE V

WEATHEROMETER DATA

S/N 155 10K FUEL UNIROYAL



Tensile Strength - Fed Std 191 Method 5102

Elongation - Fed Std 191 Method 5102

Tongue Tear - Fed Std 191 Method 5134

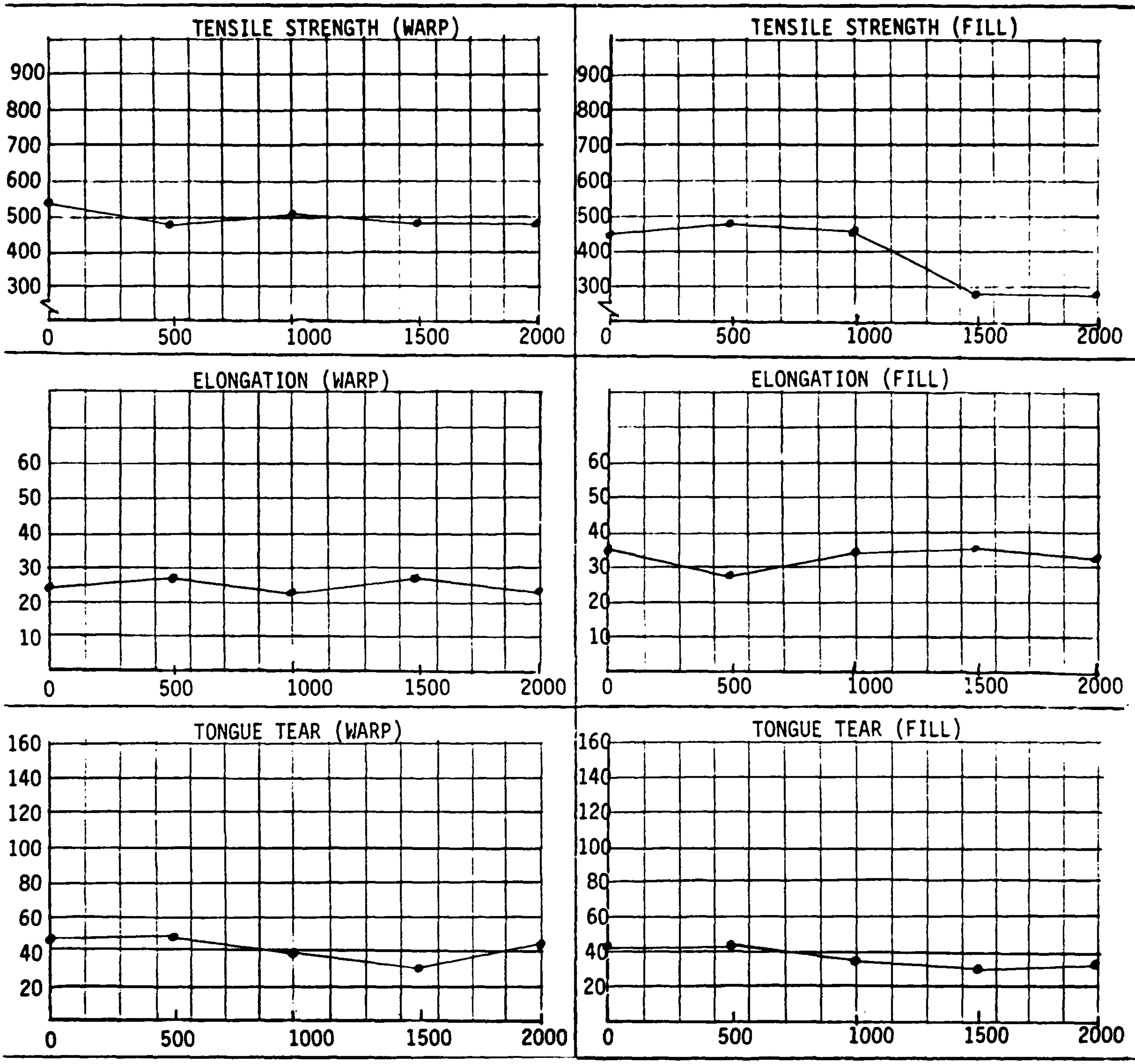
X Axis - Weatherometer Aging in Hours

Y Axis - Properties as shown

TABLE VI

WEATHEROMETER DATA

S/N 794 10K FUEL ILC



Tensile Strength - Fed Std 191 Method 5102

Elongation - Fed Std 191 Method 5102

Tongue Tear - Fed Std 191 Method 5134

X Axis - Weatherometer Aging in Hours

Y Axis - Properties as shown

Good physical property retention was achieved by all tank materials tested. The following are the properties, by tank, which fell below an 80% retention level at 2000 hours exposure:

TANK	PROPERTY RETENTION BELOW 80%	
Uniroyal S/N W150 50K Water Tank	None	
Goodyear S/N 84-25727 20K Water Tank	Tensile Strength	F=71.4%
	Tongue Tear	W=68.9%
Uniroyal S/N W155 10K Fuel Tank	Tongue Tear	W=73.6%
ILC Dover S/N 794 10K Fuel Tank	Tensile Strength	F=60.9%
	Tongue Tear	F=76.1%

All physical properties of all tanks tested were well within a safety factor of two for supporting tank stress loadings when filled regardless of the % retention figures. See Table VIII showing tank wall stress figures for each tank tested.

It is apparent that an exposure of 2000 hours in a weatherometer is not sufficient to initiate significant degradation of the nylon fabric to duplicate conditions in the field, which could result in catastrophic failure of a tank due to degradatiion of the reinforcing member to the point where the construction will no longer support the wall stress loading encountered during service.

5.0 TASK II FUEL IMMERSION TESTING

5.1 Immersion testing was run on each of two fuel tank constructions, as outlined in MIL-T-52983C; Table III - Item 12, Table IV - Items 3 and 7 and Table V - Items 3 and 7.

These fuel tests were run using two test media as follows:

MIL-F-46162C (diesel) plus 1 volume % of ethylene glycol monomethyl ether added, and Fuel B with no additives.

Sufficient samples were removed from the tanks to obtain results after 0, 14, 28 and 42 day immersions. Agings were run at 160°F +/- 2°F in a Blue M controlled temperature bath. Shear and peel adhesion measurements were made on a Scott CRE Model #2, equipped with a 2000 pound capacity load cell.

The results of this testing is presented in Table VII.

TABLE VII

FUEL IMMERSION TEST RESULTS

TEST PER TABLES III & IV OF MIL-T-52983B			S/N 794 ILC	S/N 155 UNI	MIL-T-52983 SPEC
SEAM SHEAR	Original		320 *	618	350
	14 day Fuel B @ 160°F		369	647	315
	28 day Fuel B @ 160°F		345	610	---
	42 day Fuel B @ 160°F		395	537	---
	14 day MIL-F-46162B fuel + EGME ** @ 160°F		386	555	---
	28 day MIL-F-46162B fuel + EGME @ 160°F		354	481	---
	42 day MIL-F-46162B fuel + EGME @ 160°F		361	500	---
SEAM PEEL	Original		21.7 IS*** 33.3 OS	60.3	20
	14 day Fuel B @ 160°F		19.0 IS 27.3 OS	49.3	10
	28 day Fuel B @ 160°F		20.7 IS 28.0 OS	31.7	---
	42 day Fuel B @ 160°F		28.0 IS 21.5 OS	21.7	---
	14 day MIL-F-46162B fuel + EGME @ 160°F		24.7 IS 31.7 OS	43.0	---
	28 day MIL-F-46162B fuel + EGME @ 160°F		30.3 IS 26.3 IS	26.7	---
	42 day MIL-F-46162B fuel + EGME @ 160°F		25.8 IS 33.7 OS	20.0	---
FITTING SHEAR	Original	Straight	771	612	350
		Curved	277	874	
	14 day Fuel B @ 160°F	Straight	555	620	315
		Curved	181	874	
	28 day Fuel B @ 160°F	Straight	451	524	---
		Curved	377	444	---
	42 day Fuel B @ 160°F	Straight	465	478	---
		Curved	320	456	---
	14 day MIL-F-46162B fuel + EGME @ 160°F	Straight	616	641	---
		Curved	263	647	---
	28 day MIL-F-46162B fuel + EGME @ 160°F	Straight	461	411	---
		Curved	320	444	---
	42 day MIL-F-46162B fuel + EGME @ 160°F	Straight	449	468	---
		Curved	409	534	---

TABLE VII (Continued)

FUEL IMMERSION TEST RESULTS

* Low originals probably is testing anomoly since aged values are high and originals broke outside seam.

** Ethylene Glycol Monomethyl Ether

*** ILC tank contained butt seams - IS = Inside Seam
- OS = Outside Seam

The seam peel and shear test results show excellent performance of both tanks when subjected to each of the test fluids for 14, 28 and 42 days at 160°F. In fact, both tank constructions meet or exceed the original test requirements after 42 days immersion in each test fluid.

The test results for fitting shear also show good results except for the curved section of the access door cut from the ILC tank and tested for originals: 14 day Fuel B and 14 day MIL-F-46162B fuel + EGME. These values fell below MIL-T-52983C specification requirements. However, the averages of the straight and curved sections passed and the 28 and 42 day values for the curved sections were well above the specification minimums.

6.0 TASK III DETERMINATION OF NON-DESTRUCTIVE TEST METHODS

6.1 Definition of Non-Destructive Test Methods

Uniroyal Plastics Company's approach to development of a non-destructive test method for prediction of tank service life was based on determination of the tank's ability to withstand the hoop stresses necessary to sustain it in service. This approach involved the measurement of the tank material's remaining elongation at a stress level equal to the wall tension it will experience in service when filled to capacity, then correlating this measurement with: (1) data obtained from seven tanks of various ages up to ten years, (2) strain data obtained from weatherometer agings, and (3) carbon/oxygen data obtained from weatherometer aging and aged tank samples. Measurement of the strain at a given stress was accomplished through the use of a mechanical strain gage clamped to the tank body material and across the seams in a manner which did not affect the tank integrity. Uniroyal understood that this, and any type of approach to determine remaining tank service life, was dependent upon the type of reinforcement and polymer coating used to fabricate a tank. Correlation to actual field life performance could only be attempted on tanks manufactured by Uniroyal. Correlation of data on other constructions was only limited to the determination of a tank fit-for-use at the time of test, with projected service life based only on accelerated weathering and carbon/oxygen ratio measurements.

Uniroyal Plastics Company, Inc. executed the followng five-phase effort aimed at determining a non-destructive test method for determination of "as-is" fit-for-use determination and projected service life determinations.

PHASE I — Mechanical strain measurements on unfilled tanks using a "clamp-on" strain measuring device.

PHASE II — Determination of tank strain measurements on tanks filled to rated capacity.

PHASE III	Stress/strain and tear measurements made on weatherometer aged tank samples and field aged tank samples.
PHASE IV	Determination of carbon/oxygen ratios of polymer coating compounds on weatherometer aged and field aged tank samples.
PHASE V	Correlation of data from PHASES I - IV into conclusions and recommendations to predict tank integrity and future life expectancy.

6.2 PHASE I - Measuring strain measurements on unfilled tanks using a "clamp-on" strain measuring device:

Uniroyal Plastics Company, Inc. developed a "clamp-on" strain measuring device which is capable of introducing a predetermined stress on the tank body wall. (See Figure 1 for detailed drawing of tester.) By measuring the distance, the jaws of the clamp-on fixture have moved from no tension to the calculated wall stress at filled capacity. A measurement of the % strain at this given load can then be calculated. A description of the use of this test fixture is detailed in Appendix II of this report.

Table VIII (page 17) details the measurements taken on eleven tanks using the test device under the column marked "machine". The individual values reported for body panels and across seams are the average of four values taken at different locations on the tank, i.e., across four different seams and four different tank panels.

Our original test plan called for testing across fittings and across end closure seams. However, during the design of the fixture it was determined that if the two support bars were made long enough to span the distance necessary to test these two areas, significant bending of these bars would result, thus adversely affecting any test data obtained. Because of this situation, these tests were not run.

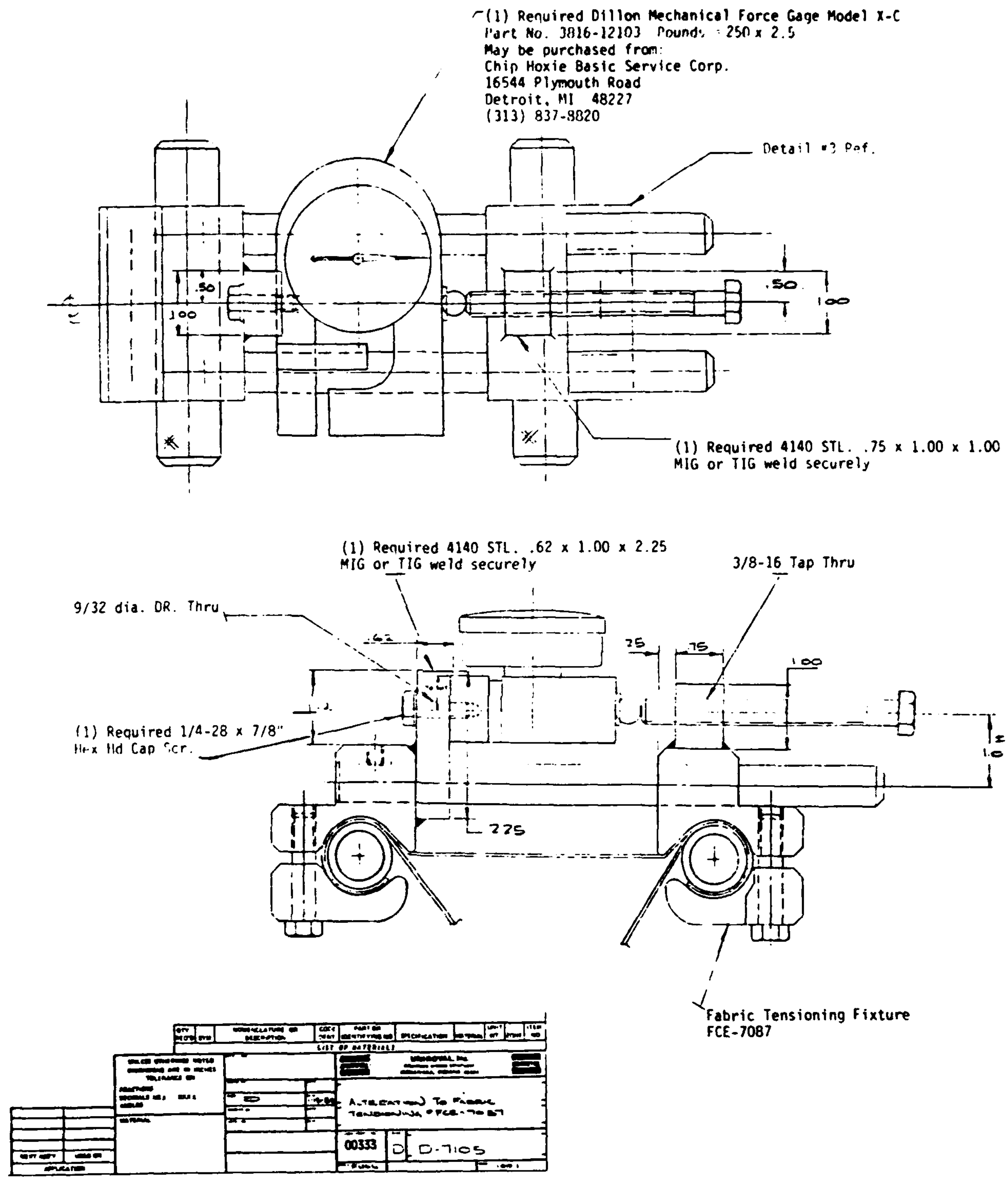
These test results indicate that each tank tested supported the calculated wall stress at relatively low elongations, indicating that each area tested could sustain the load incurred if the tank were filled to its rated capacity.

One conclusion that can also be made is that the fill strains at the test stress loadings are consistently higher than for the warp direction, regardless of material type. This is probably due to the larger crimp associated with the fill direction.

Testing of the eight locations required approximately three hours of time, including unrolling and rerolling the tank. Equilibration time was determined to be two minutes to five minutes.

These test results will be further discussed in the TASK III, PHASE V section.

FIGURE 1


(1) Required Dillon Mechanical Force Gage Model X-C
Part No. 3816-12103 Pounds = 250 x 2.5
May be purchased from:
Chip Hoxie Basic Service Corp.
16544 Plymouth Road
Detroit, MI 48227
(313) 837-8820
Detail #3 Ref.
.50
1.00
(1) Required 4140 STL. .75 x 1.00 x 1.00
MIG or TIG weld securely
(1) Required 4140 STL. .62 x 1.00 x 2.25
MIG or TIG weld securely
3/8-16 Tap Thru
9/32 dia. DR. Thru
.62
.75
.75
1.00
(1) Required 1/4-28 x 7/8" Hex Hd Cap Scr.
.225
Fabric Tensioning Fixture
FCE-7087
LIST OF MATERIALS
00333
D-7105

6.3 PHASE II - Determination of tank strain measurements on tanks filled to rated capacity:

The eleven tanks used in Phase I were marked with strain rosettes as shown in Figure 2, page 19. These indicator lines (20" in length), were placed on the tank so that measurements before and after filling to rated capacity could be made. By dividing the difference between the filled length and the unfilled length, a % strain figure can be calculated. These figures can then be correlated to the figures obtained from the "clamp-on" fixture.

Each of the eleven tanks to be water filled were 1/2 psi air soap tested prior to water filling to ensure they were serviceable tanks. Since the strain rosettes had already been placed on the tank, measurements were made to determine the strain characteristics of each tank when subjected to the 1/2 psi leak test. This data was gathered for information purposes only and is presented in Table VIII on page 17.

Each tank was allowed to "relax" for at least one week prior to being water filled.

Initial rosette measurements were again made on each tank to be water filled. Each water tank was then filled to its rated gallon capacity and each fuel tank was filled with water to a gallon amount equal to the weight of fuel for its rated capacity (water S.G. = 1, fuel S.G. = .795). These water filled gallonages are shown in Table VIII.

The tanks were allowed to equilibrate for seven days in a filled condition prior to taking measurements of the strain rosettes. This seven day figure was arrived at by measuring the first few filled tanks every day until the measurements came out the same as the previous day. The strain measurements, along with the calculated wall stresses, are shown for each tank in Table VIII on page 17. Each of the strain measurement figures represents the average of four individual readings taken from each tank.

The data shows that the wall stresses experienced during the 1/2 psi air test are over three times those experienced by 10K tanks when filled with fuel or water to their rated capacity; the larger tanks (20 - 50K) are stressed 1.37 to 2.25 times their filled stress levels. At these high stress levels (48.1 - 63.0 lbs/in) the minimum tear strength by specification (35 lbs) is being exceeded. Using the 1/2 psi specification test on an old tank containing some defect, which could act as a tear initiation point, could cause a tank to fail catastrophically during testing.

TABLE VIII
TANK STRAIN TEST DATA

TANK	FUEL/ WATER	MFGR *	SIZE	MFG. DATE	GAL H_2O	TANK DIMENSIONS L	TANK DIMENSIONS W	STRESS #/in ***	STRAIN % W	(MACHINE) % F	ACR SE
S/N W510	F	U	10K	5/81	9073	21'11"	21'11"	14.3	1.5	3.0	2.
S/N W358	F	U	42K	7/84	38453	54'7"	29'9"	28.03	1.4	2.6	1.
S/N W9	F	U	10K	10/84	9121	21'3"	21'9"	16.34	.9	1.4	1.2
S/N W1109	F	U	20K	2/85	18335	28'0"	24'1"	46.0	2.1	6.8	4.1
S/N W155	F	U	10K	11/85							
S/N W158	F	U	10K	11/85	9152	21'10"	21'10"	14.81	1.34	1.59	1.3
S/N 794	F	I	10K	3/85	9165	21'5"	21'6"	16.5	1.275	2.175	1.5
S/N 6	W	U	10K	5/77	10000	29'2"	17'4"	17.04	1.5	2.7	2.8
S/N W1	W	U	20K	10/81	20000	28'7"	24'10"	35.3	3.2	7.6	7.3
S/N W150	W	U	50K	3/83							
S/N W122	W	U	50K	2/83	50000	65'4"	25'4"	35.0	1.9	4.9	4.4
S/N W2	W	U	10K	7/84	10000	22'6"	22'0"	16.81	1.8	2.2	2.7
S/N 84-25727	W	G	20K	2/83							
S/N 84-13805	W	G	20K	2/84	20000	28'3"	24'3"	40.0	1.9	6.0	5.4

* U=Uniroyal, G=Goodyear, I-ILC
** Calculated wall stress at 1/2 psi using actual tank dimensions
*** Calculated wall stress at rated volume using actual tank dimensions
Water S.G. = 1 Fuel S. G. = .795

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TABLE VIII
TANK STRAIN TEST DATA

AL O	TANK DIMENSIONS L	W	STRAIN (MACHINE) STRESS #/in ***	% W	% F	ACROSS SEAM	STRAIN (WATER FILL) STRESS #/in ***	FILL HEIGHT	% W	% F	STRAIN (1/2 PSI A STRESS #/in **	% W	% F
73	21'11"	21'11"	14.3	1.5	3.0	2.9	14.3	39.8"	1.25	6.41	51.0	5.0	16.6
53	54'7"	29'9"	28.03	1.4	2.6	1.8	28.03	55.73"	2.34	5.47	63.0	2.5	3.1
1	21'3"	21'9"	16.34	.9	1.4	1.2	16.34	42.5"	1.10	2.74	51.4	2.2	5.5
35	28'0"	24'1"	46.0	2.1	6.8	4.1	46.0	63.6"	3.125	9.85	59.6	3.1	10.0
2	21'10"	21'10"	14.81	1.34	1.59	1.36	14.81	43.0"	1.72	4.22	51.0	2.3	5.5
5	21'5"	21'6"	16.5	1.275	2.175	1.54	16.5	42.8"	2.03	6.56	50.0	3.125	8.91
00	29'2"	17'4"	17.04	1.5	2.7	2.8	17.04	43.5"	1.0	4.8	54.0	2.2	7.8
00	28'7"	24'10"	35.3	3.2	7.6	7.3	35.3	62.5"	2.81	9.69	62.2	3.0	12.2
00	65'4"	25'4"	35.0	1.9	4.9	4.4	35.0	62.3"	2.3	7.5	48.1	1.7	8.4
00	22'6"	22'0"	16.81	1.8	2.2	2.7	16.81	43.2"	1.41	4.22	52.0	3.3	8.0
00	28'3"	24'3"	40.0	1.9	6.0	5.4	40.0	62.3"	4.4	11.6	61.0	2.5	10.0

si using actual tank dimensions
volume using actual tank dimensions
795

Formula Used For Air Stress Calculation

$T=(.70711)\left(Px\ \frac{A+B}{4}\ X\ 1.1\right)$

Where T=wall stress in lbs
Px=air pressure in psi
A=tank width in inches
B=tank length in inches

Formula Used For Water Fill Stress Calculations

$T=1/4\ \sigma\ Z^2$

Where T=wall stress in lbs
σ=Sp Wt of water=.0361 #/
Z=tank height in inches

As expected, the strain readings obtained using the "clamp-on" fixture are different than those obtained when the tank is filled to its rated capacity. The strains using the fixture are lower due to the participation of the adjacent fabric in the strain reading. To develop a factor to convert the machine strain reading to the actual strain figure, a conversion factor can be developed. Table IX below shows Uniroyal tanks of the same fabric reinforcement and type and what the factors are for each of the warp and fill direction. This factor was obtained by dividing the machine strain figure by the actual strain value.

TABLE IX

STRAIN CORRELATION FACTORS

SERIAL NUMBER	TYPE	FACTOR W	FACTOR F
S/N W9	Fuel	.82	.51
S/N W240	Fuel	.68	.49
S/N W358	Fuel	.60	.47
S/N W1109	Fuel	.67	.69
S/N W158	Fuel	.78	.56
	Ave.	.71	.54
	Range	+/-15%	+/-20.4%
S/N W6	Water	1.50	.56
S/N W1	Water	1.14	.78
S/N W2	Water	1.28	.52
S/N W122	Water	.83	.65
	Ave.	1.18	.62
	Range	+/-28.4%	+/-21.0%

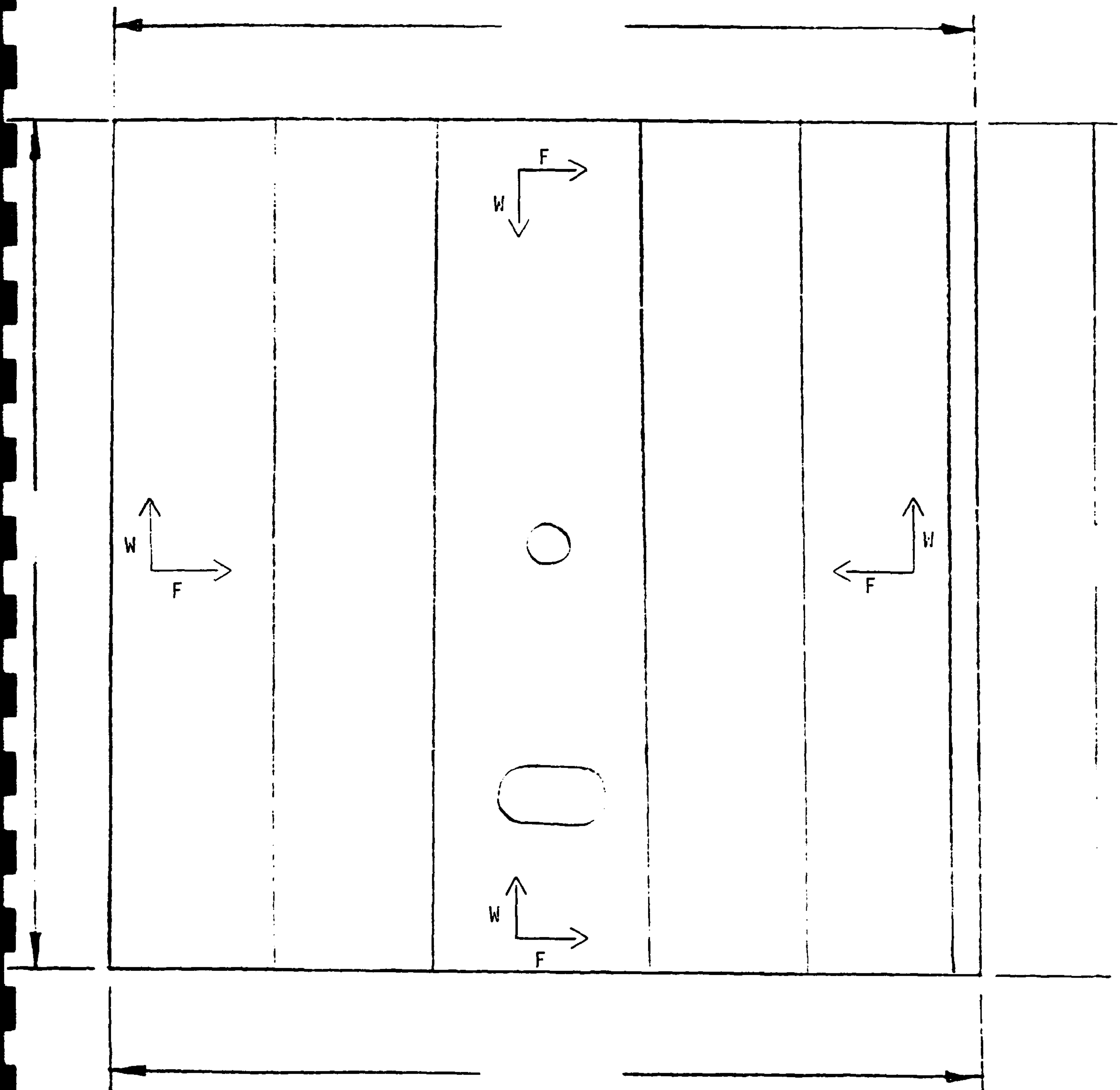
Table IX shows that the actual strain can be calculated from the test fixture strain figure by dividing it by the correlation factor, but the error factor is quite high (15 - 28.4%). This relatively high error factor may be due to the relatively small sample size.

The results of the water fill data and the correlation of it to the "clamp-on" test fixture data will be further discussed in the Task III, Phase V section.

FIGURE 2

WATER FILLED TANK
STRESS/STRAIN MEASUREMENT DIAGRAM

10K TANK
(example)



NOTE: Strain rosette dimensions are 20" in length

6.4 PHASE III Stress/strain and tear measurements made on weatherometer aged and field aged tank samples:

Task I data included W and F tear strength measurements on weatherometer aged sections of the government supplied tanks (see Tables III through VI). This data will be required for the correlation section (Phase V) of this task.

Uniroyal Plastics Company, Inc. originally planned to graph the stress vs strain properties vs weatherometer properties for each of the four tank types tested. The graph was to take the form of the one shown below in Figure 3.

Stress vs Strain for Each Weatherometer Exposure Period

```
                X:                                    0 hours
Stress           :                                  500 hours
#/in             :                                 1000 hours
                 :                                 1500 hours
                 :                                 2000 hours
                O:________________________________Y

                       Strain (%)
```

FIGURE 3

It became apparent after completing the weatherometer agings that a testing period of 2000 hours is not sufficient to show any meaningful drop in physical properties. See tensile and elongation graphs in Tables III through VI. Graphic representation as shown in Figure 3 above only shows data scatter and does not reflect meaningful changes in the physical properties, hence these graphs will not be presented.

Graphic representation of the stress/strain curves for the four government supplied tanks has been done for each weatherometer aging period and is presented in Figures 4 through 23.

Body panels were removed from each of the seven Uniroyal supplied tanks to run tear test (W & F) per Federal Standard 191, Method 5134 and tensile/elongation tests per Federal Standard 191, Method 5102. Tensile and elongation tests were run on a chart recorder so that a stress vs strain curve could be developed. The plots of stress vs strain for each of the eleven tanks are presented in Figures 24 through 34. The ultimate tensile, ultimate elongation and tear test results are presented in Table X for all eleven tanks tested.

TABLE X

TENSILE, ELONGATION, TEAR TEST RESULTS FOR ALL TANKS TESTED

TANK (FUEL)	MFG	AGE * YEARS	TENSILE W	TENSILE F	ELONGATION W	ELONGATION F	TONGUE TEAR W	TONGUE TEAR F	HISTORY
UNI S/N W510 **	5/81	7.2	550	405	30	32	21	18	Outside in service
UNI S/N W358	7/84	4.0	861	759	34	50	40	34	Outside in service
UNI S/N W9	10/84	3.8	900	723	38	53	81	54	Outside in crate
UNI S/N W1109	2/85	3.4	831	412	33	53	90	86	Outside unprotected
UNI S/N W155	11/85	2.6	800	815	31	46	106	102	Inside gov't warehouse
ILC S/N 794	3/85	3.3	540	465	26	35	43	46	Inside gov't warehouse
TANK (WATER)									
UNI S/N W6	5/77	11.2	765	595	38	49	97	83	Outside in service
UNI S/N W1	10/81	7.3	681	560	35	43	121	97	Outside in crate
UNI S/N W150	3/83	4.8	770	695	31	46	146	106	Inside gov't warehouse
UNI S/N W2	7/84	4.0	793	711	39	47	108	81	Outside in crate
GDY S/N 84-25727	3/83	4.8	650	630	24	48	90	58	Inside gov't warehouse

* Age taken from date of manufacturing to 7/88

** Tank S/N W510 constructed of a lighter weight fabric than other Uniroyal tanks in this group

Plots of the data from Table X for tongue tear vs tank age by tank type are shown in Figure 35 and Figure 36.

FIGURE 35

TONGUE TEAR VS TANK AGE (FUEL)

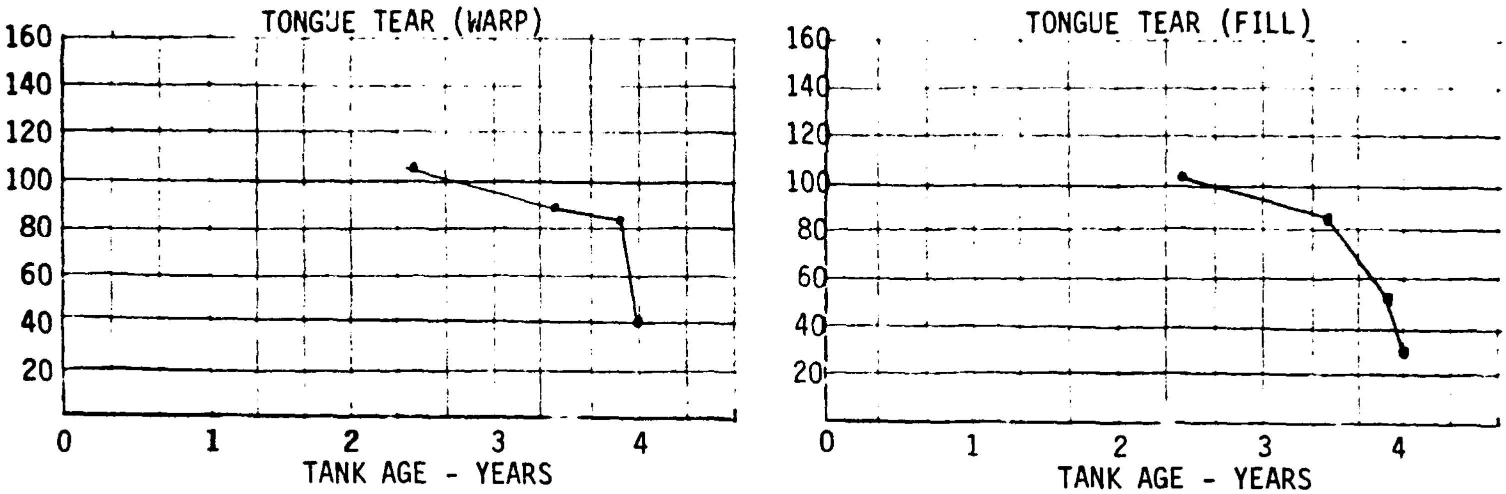
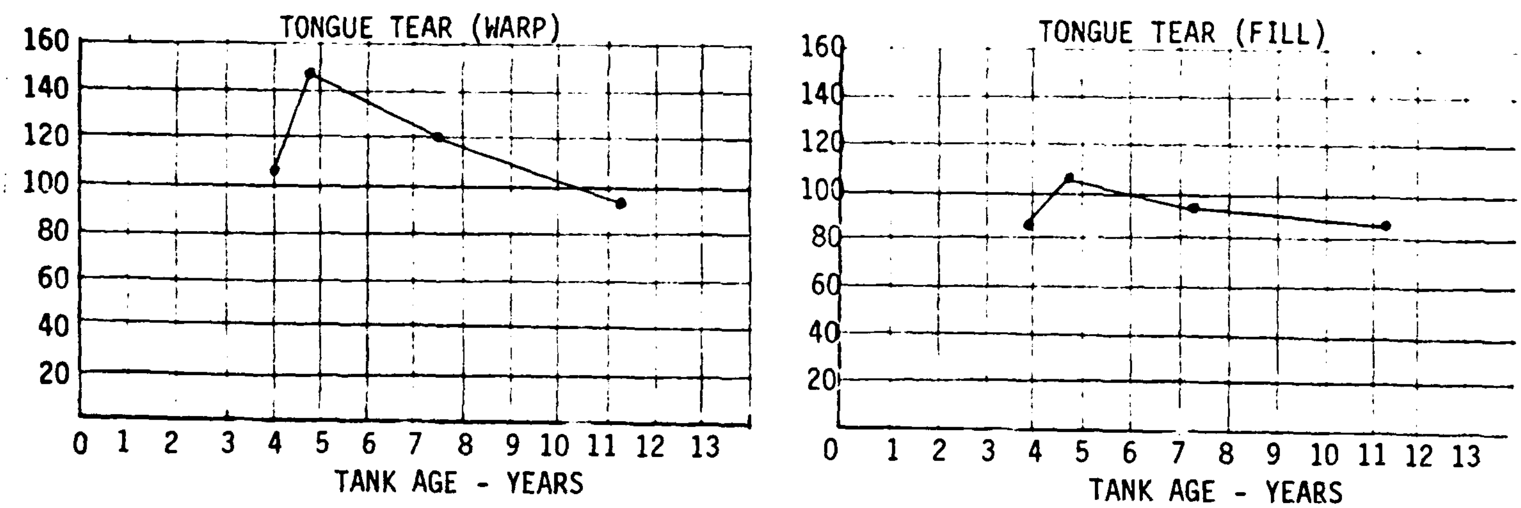


FIGURE 36

TONGUE TEAR VS TANK AGE (WATER)



Plots of the data from Figure 24 through Figure 34 for % strain vs tank age by Uniroyal tank type at the calculated max. wall stress are shown in Figure 37 and Figure 38 (max. stress value set @ 50 lbs)

FIGURE 37

% STRAIN @ 50# LOAD VS TANK AGE (FUEL)

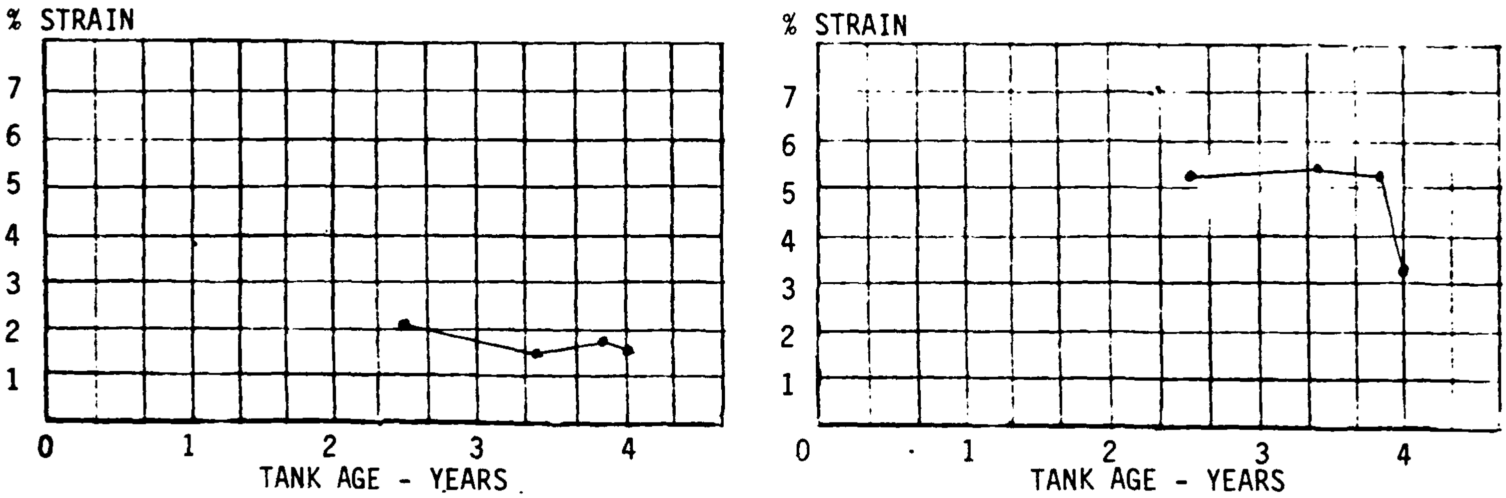
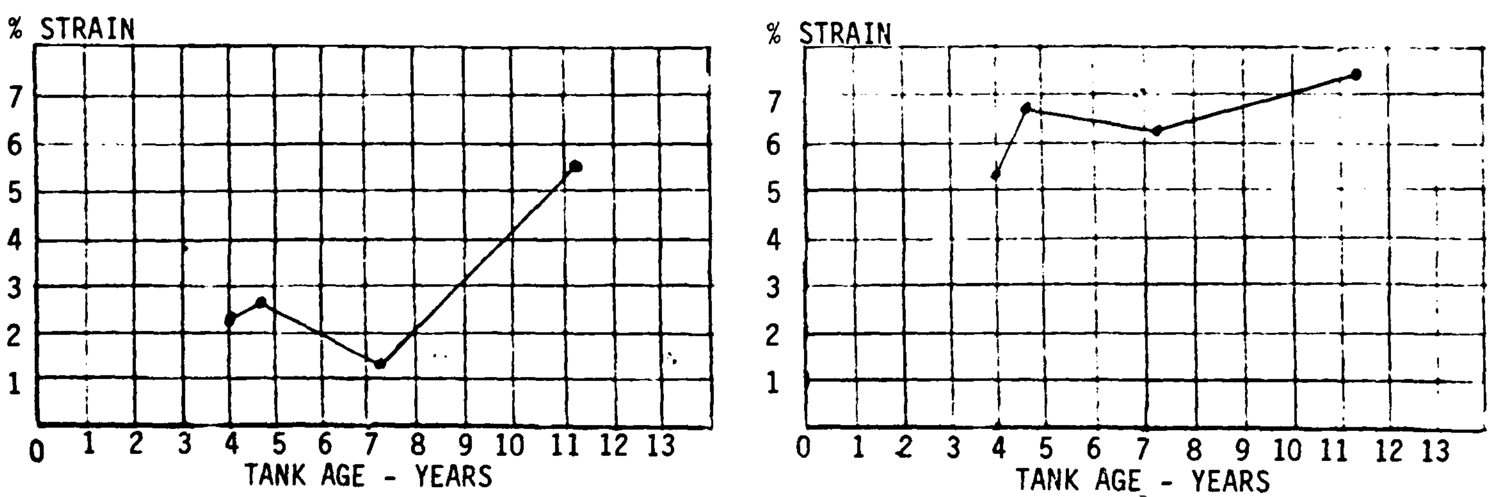


FIGURE 38

% STRAIN @ 50# LOAD VS TANK AGE (WATER)



This data will be used to correlate with the data for the weather-ometer aged samples and the data obtained in Phase I, II and IV. Correlation of this data is discussed in Phase V.

FIGURE 4

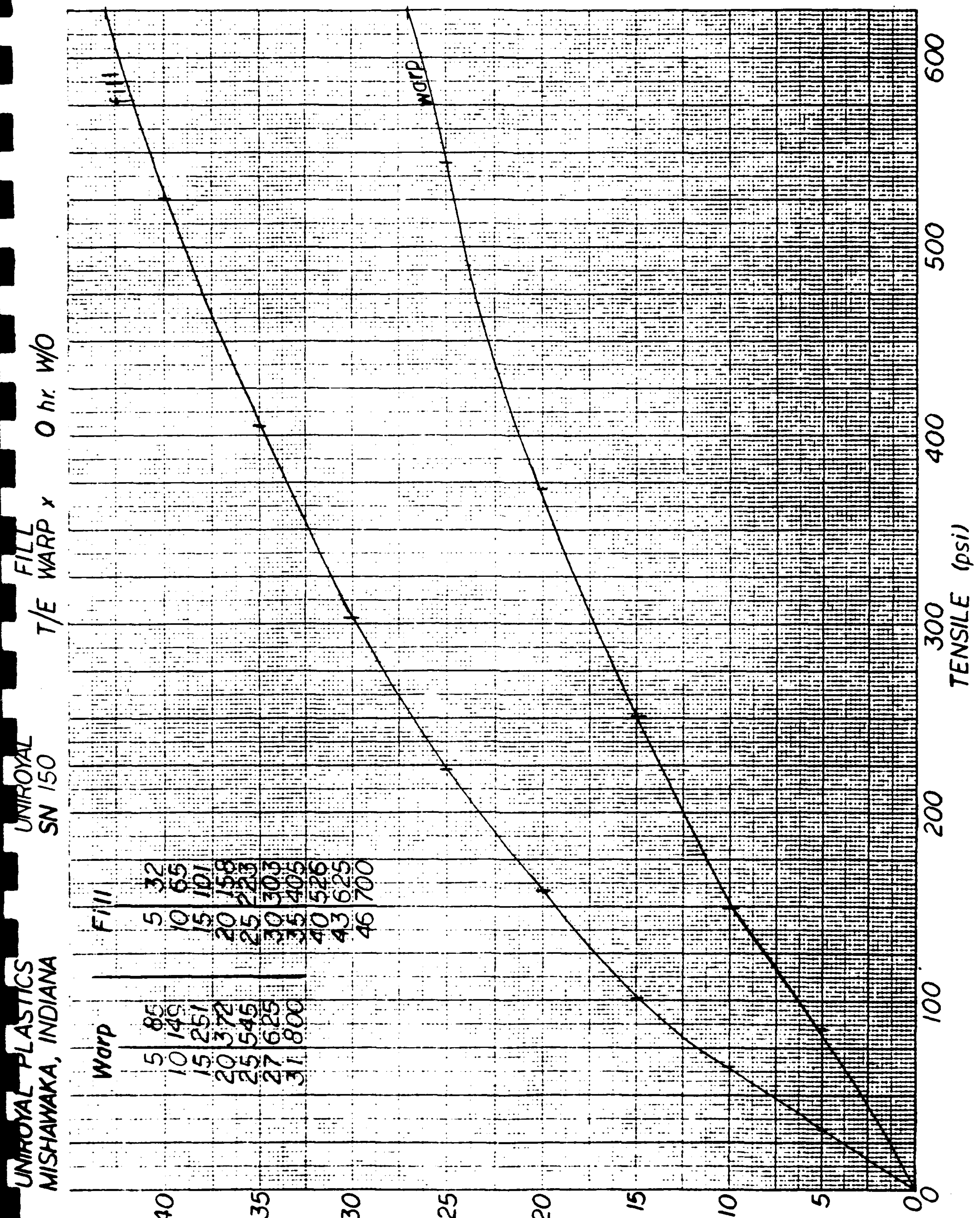
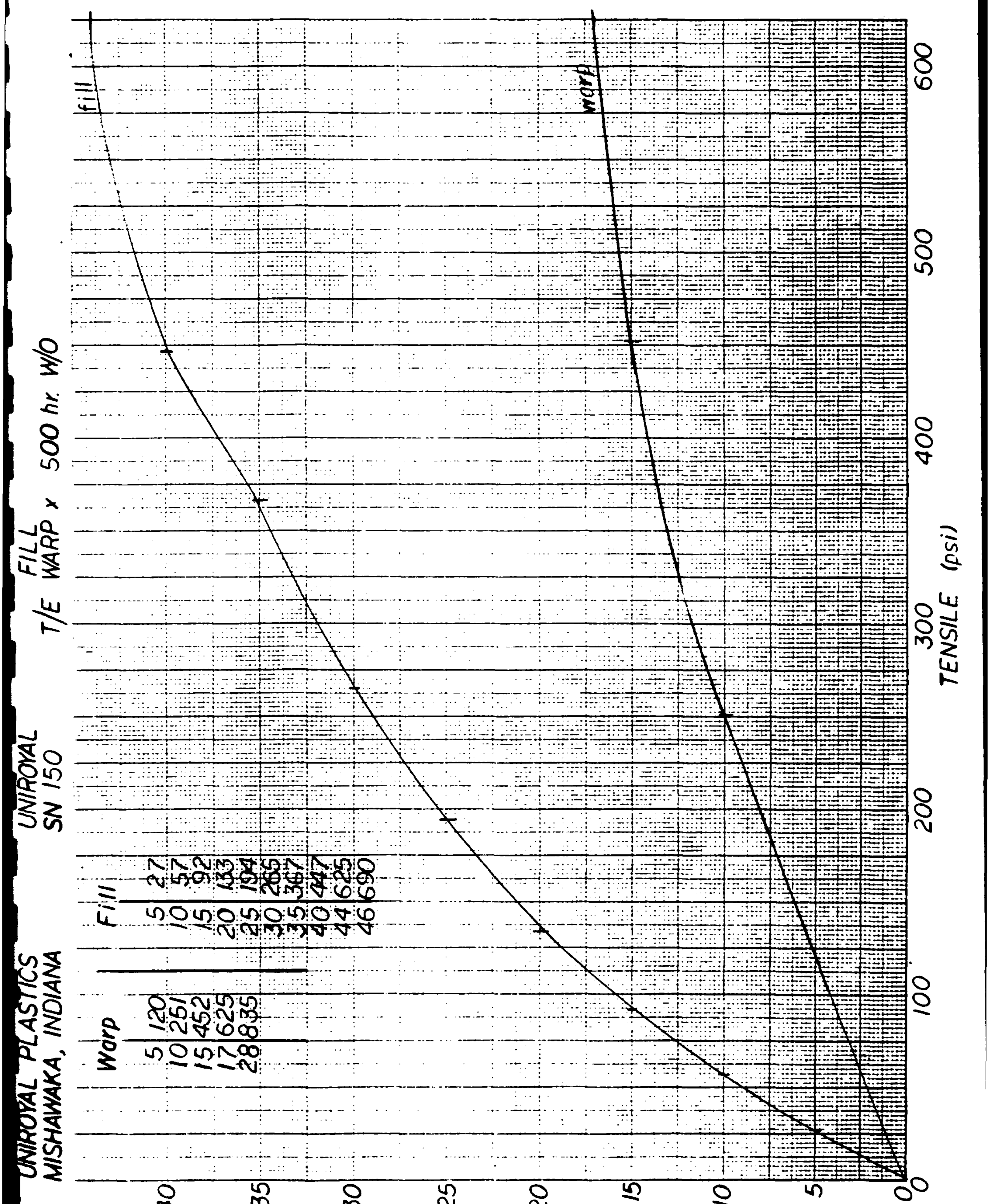

UNIROYAL PLASTICS
MISHAWAKA, INDIANA
UNIROYAL
SN 150
T/E FILL
WARP x
0 hr. W/O
Warp
5 85
10 149
15 251
20 372
25 545
27 625
31 800
Fill
5 32
10 65
15 101
20 158
25 223
30 303
35 405
40 526
43 625
46 700
Fill
Warp
% ELONGATION
TENSILE (psi)
0
5
10
15
20
25
30
35
40
100
200
300
400
500
600

FIGURE 5



UNIROYAL PLASTICS
MISHAWAKA, INDIANA
UNIROYAL
SN 150
T/E FILL WARP x 500 hr. W/O
Warp
5 120
10 251
15 452
17 625
28 835
Fill
5 27
10 57
15 92
20 133
25 194
30 265
35 367
40 447
44 625
46 690
fill
warp
0 100 200 300 400 500 600
TENSILE (psi)
0 5 10 15 20 25 30 35 40

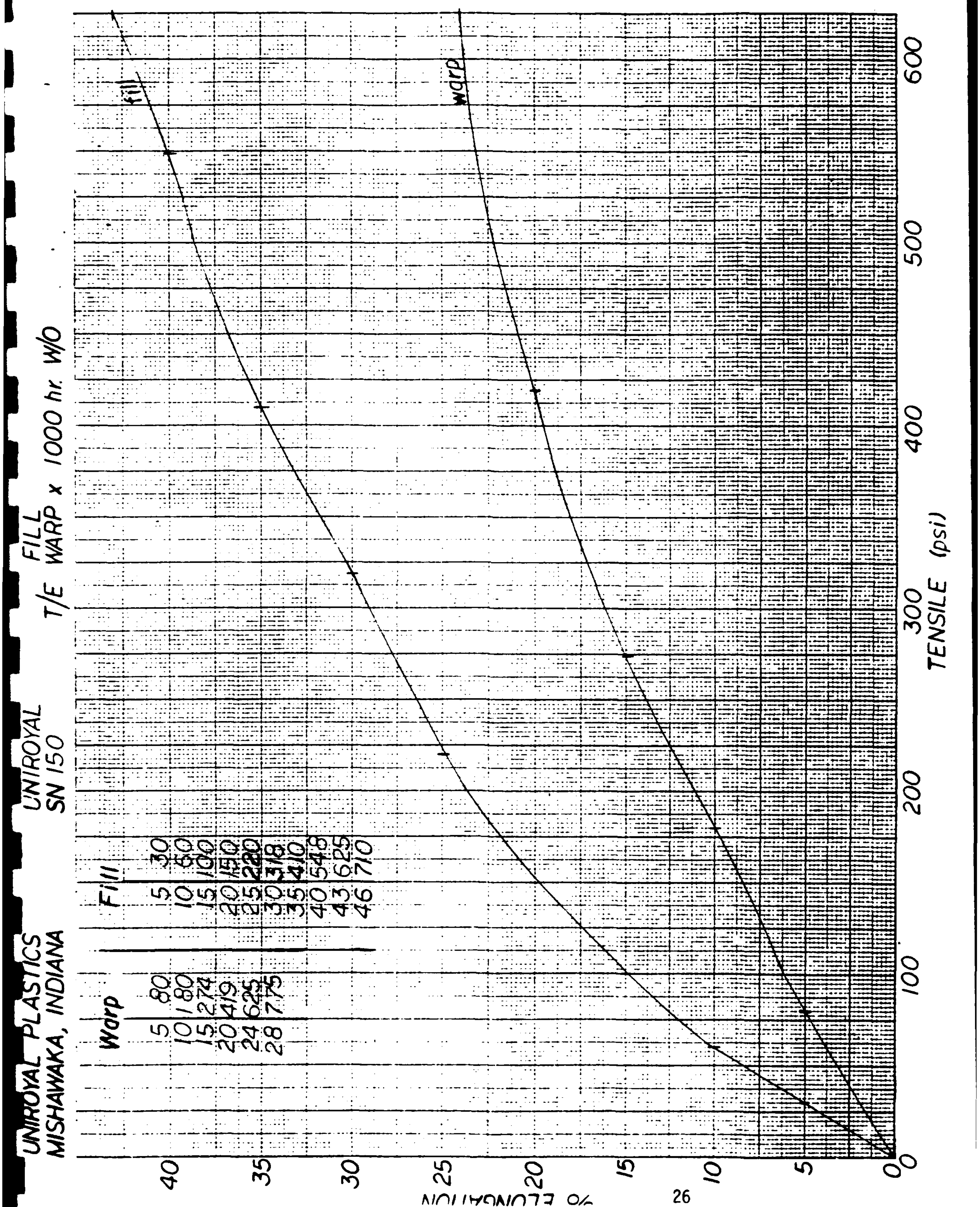
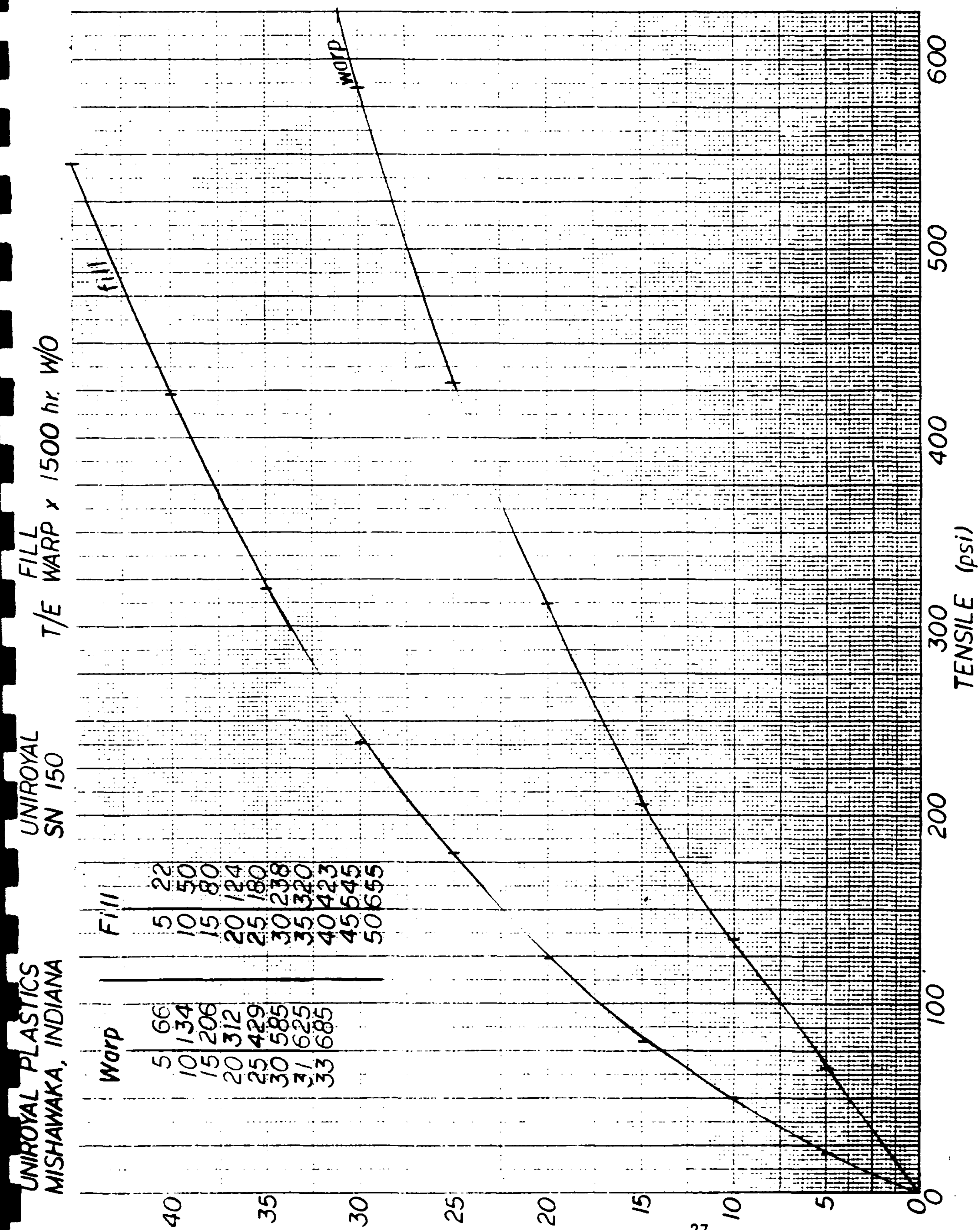

UNIROYAL PLASTICS
MISHAWAKA, INDIANA
UNIROYAL
SN 150
T/E FILL WARP x 1000 hr. W/O
Warp
5 80
10 180
15 274
20 419
24 625
28 775
Fill
5 30
10 60
15 100
20 150
25 220
30 318
35 410
40 548
43 625
46 710
fill
warp
TENSILE (psi)
% ELONGATION
0 100 200 300 400 500 600
0 5 10 15 20 25 30 35 40

FIGURE 7



UNIROYAL PLASTICS
MISHAWAKA, INDIANA
UNIROYAL
SN 150
FILL
T/E WARP x 1500 hr. W/O
Warp
5 66
10 134
15 206
20 312
25 429
30 585
31 625
33 685
Fill
5 22
10 50
15 80
20 124
25 180
30 238
35 320
40 423
45 545
50 655
warp
fill
0
5
10
15
20
25
30
35
40
0
100
200
300
400
500
600
TENSILE (psi)

FIGURE 8

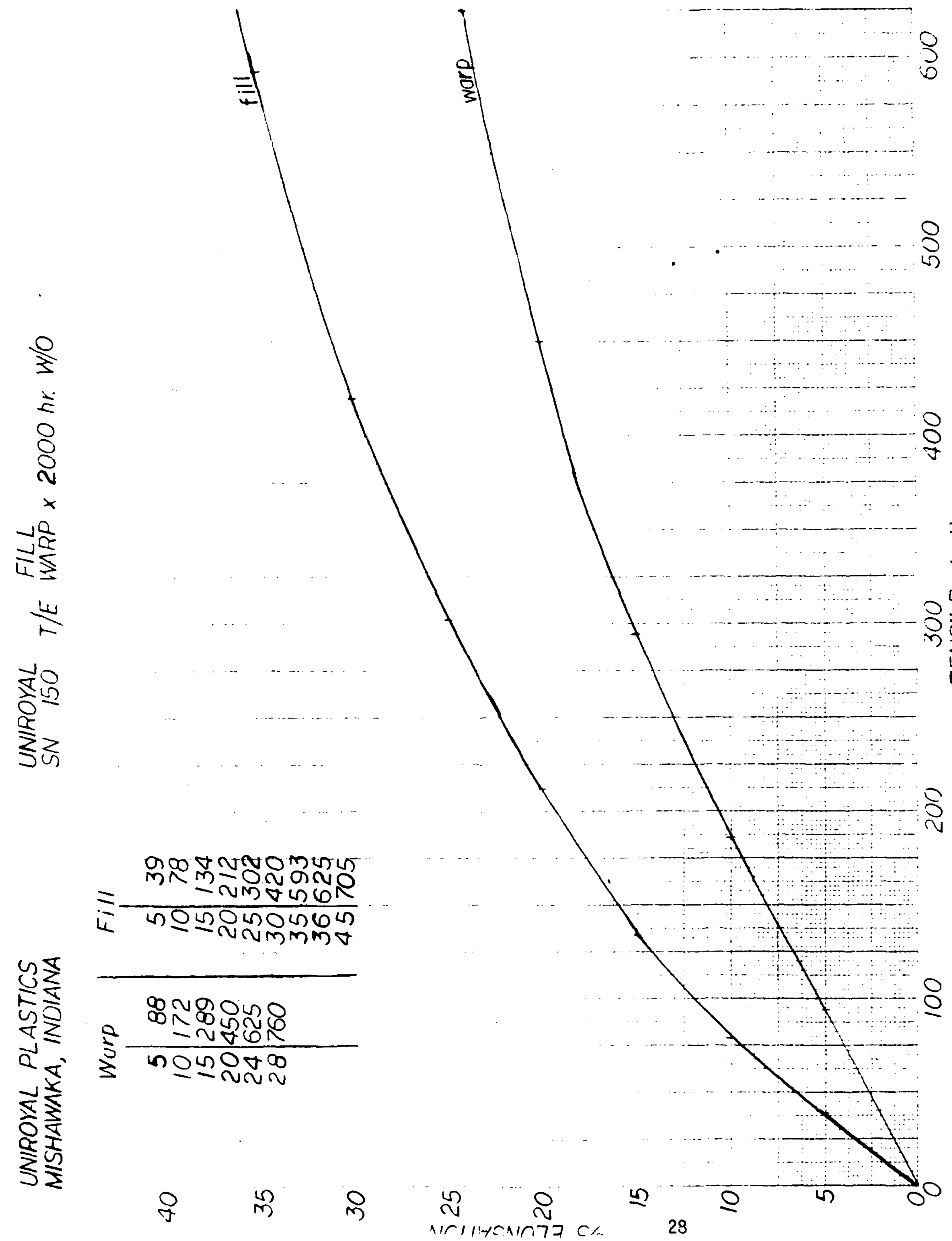

UNIROYAL PLASTICS
MISHAWAKA, INDIANA
UNIROYAL T/E FILL
SN 150 WARP x 2000 hr. W/O
Warp
5 88
10 172
15 289
20 450
24 625
28 760
Fill
5 39
10 78
15 134
20 212
25 302
30 420
35 593
36 625
45 705
fill
warp
0
100
200
300
400
500
600
TENSILE (psi)
0
5
10
15
20
25
30
35
40
% ELONGATION

FIGURE 9

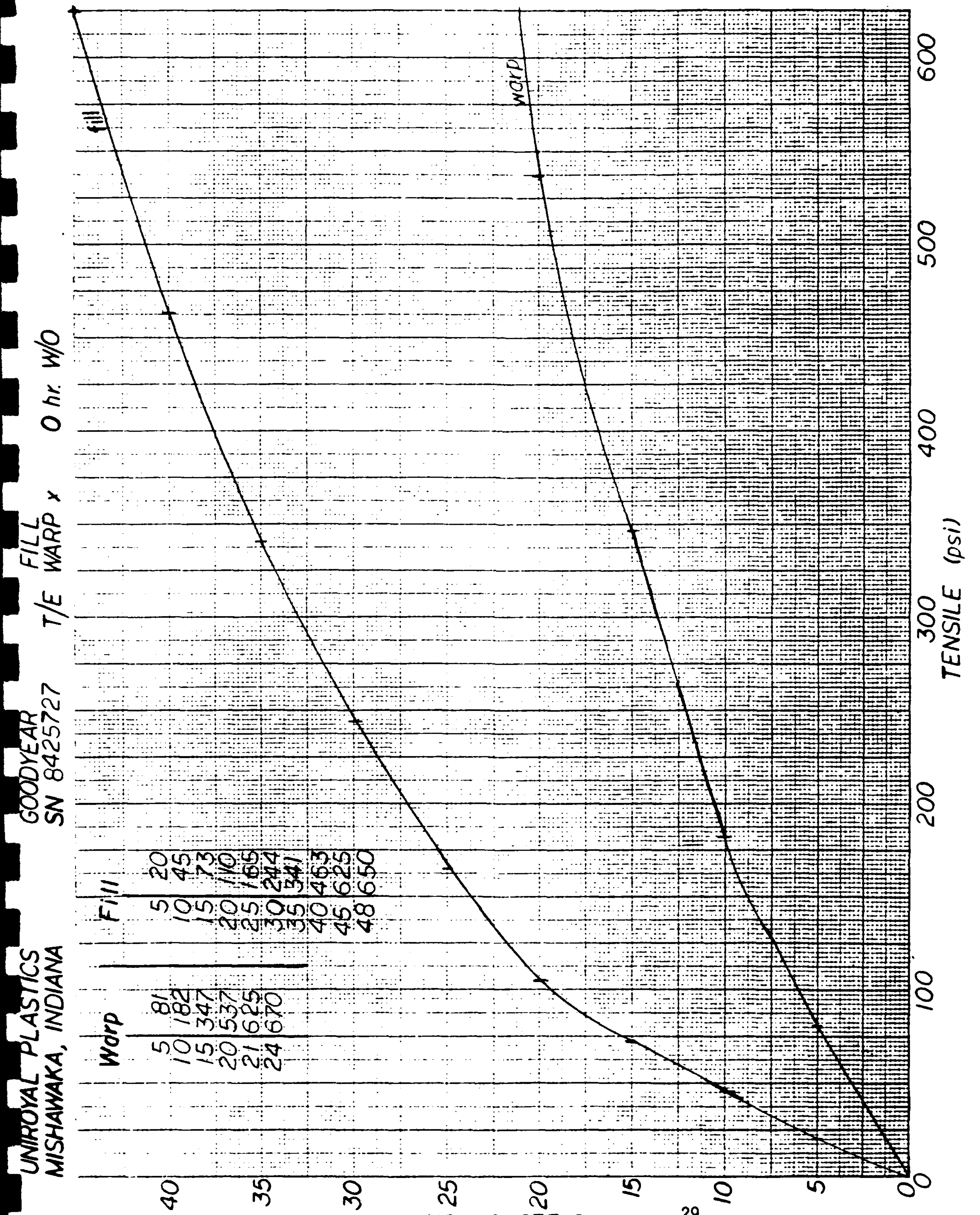

UNIROYAL PLASTICS
MISHAWAKA, INDIANA
GOODYEAR
SN 8425727
T/E FILL
WARP x
0 hr. W/O
Warp
5 81
10 182
15 347
20 537
21 625
24 670
Fill
5 20
10 45
15 73
20 110
25 166
30 244
35 341
40 463
45 625
48 650
fill
warp
TENSILE (psi)
% ELONGATION
0
100
200
300
400
500
600
5
10
15
20
25
30
35
40

FIGURE 10

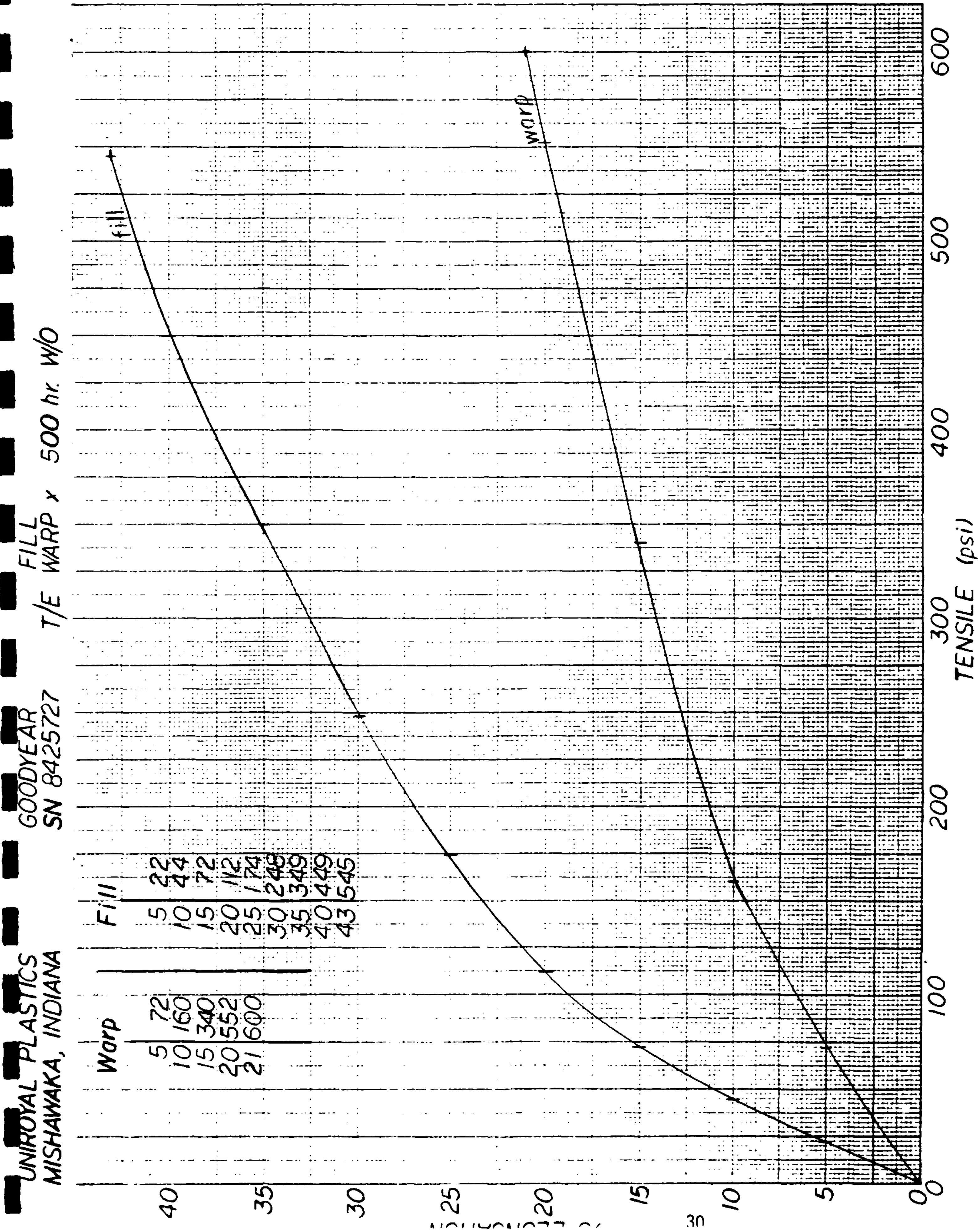

UNIROYAL PLASTICS
MISHAWAKA, INDIANA
GOODYEAR
SN 8425727
T/E FILL
WARP x 500 hr. W/O
Warp
5 72
10 160
15 340
20 552
21 600
Fill
5 22
10 44
15 72
20 112
25 174
30 248
35 349
40 449
43 545
fill
warp
TENSILE (psi)
0
100
200
300
400
500
600
0
5
10
15
20
25
30
35
40

FIGURE 11

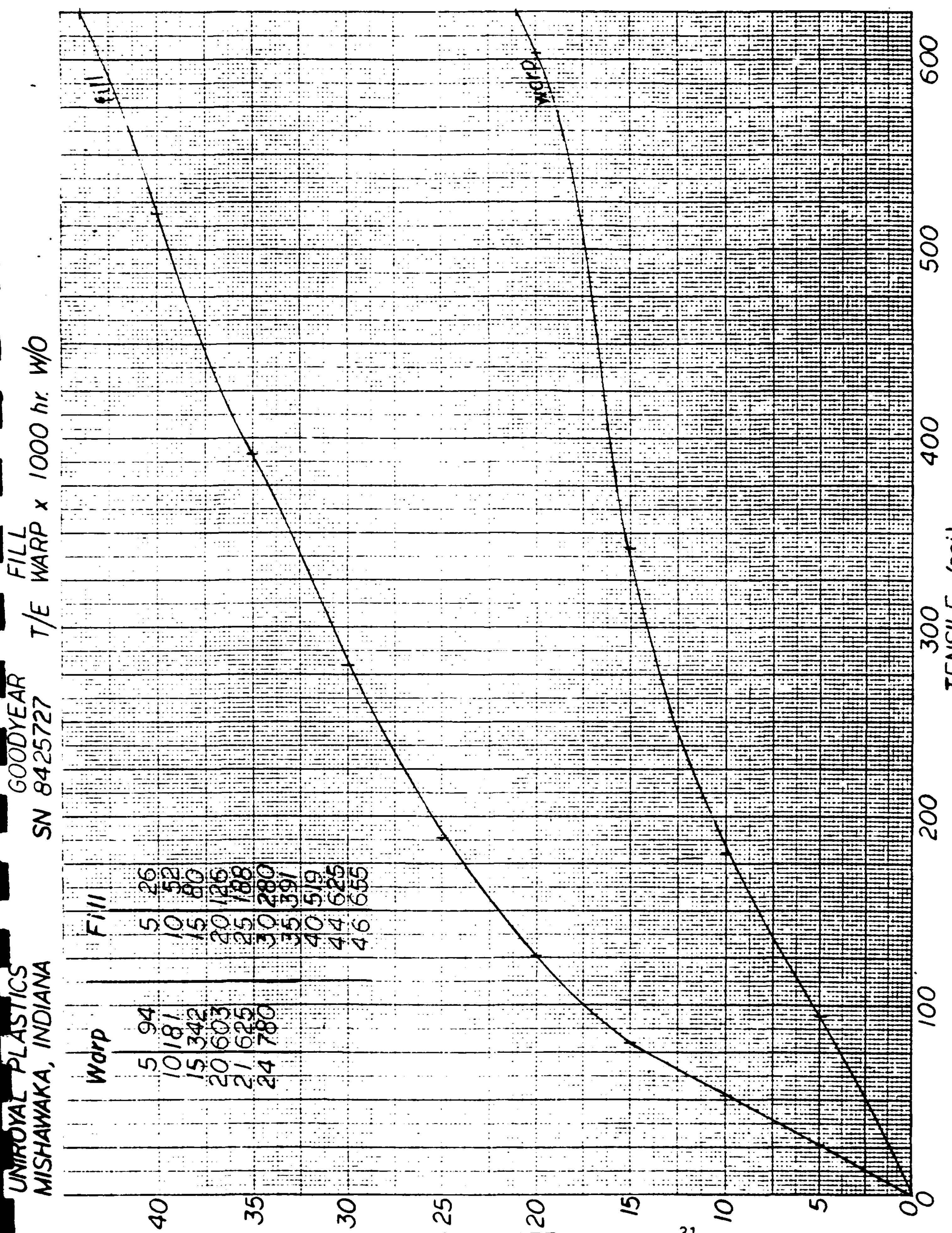

UNIROYAL PLASTICS
MISHAWAKA, INDIANA
GOODYEAR
SN 8425727
T/E FILL
WARP x 1000 hr. W/O
Warp
5 94
10 181
15 342
20 603
21 625
24 780
Fill
5 26
10 52
15 80
20 126
25 188
30 280
35 391
40 519
44 625
46 655
fill
warp
TENSILE (psi)
% ELONGATION
0 100 200 300 400 500 600
0 5 10 15 20 25 30 35 40

FIGURE 12

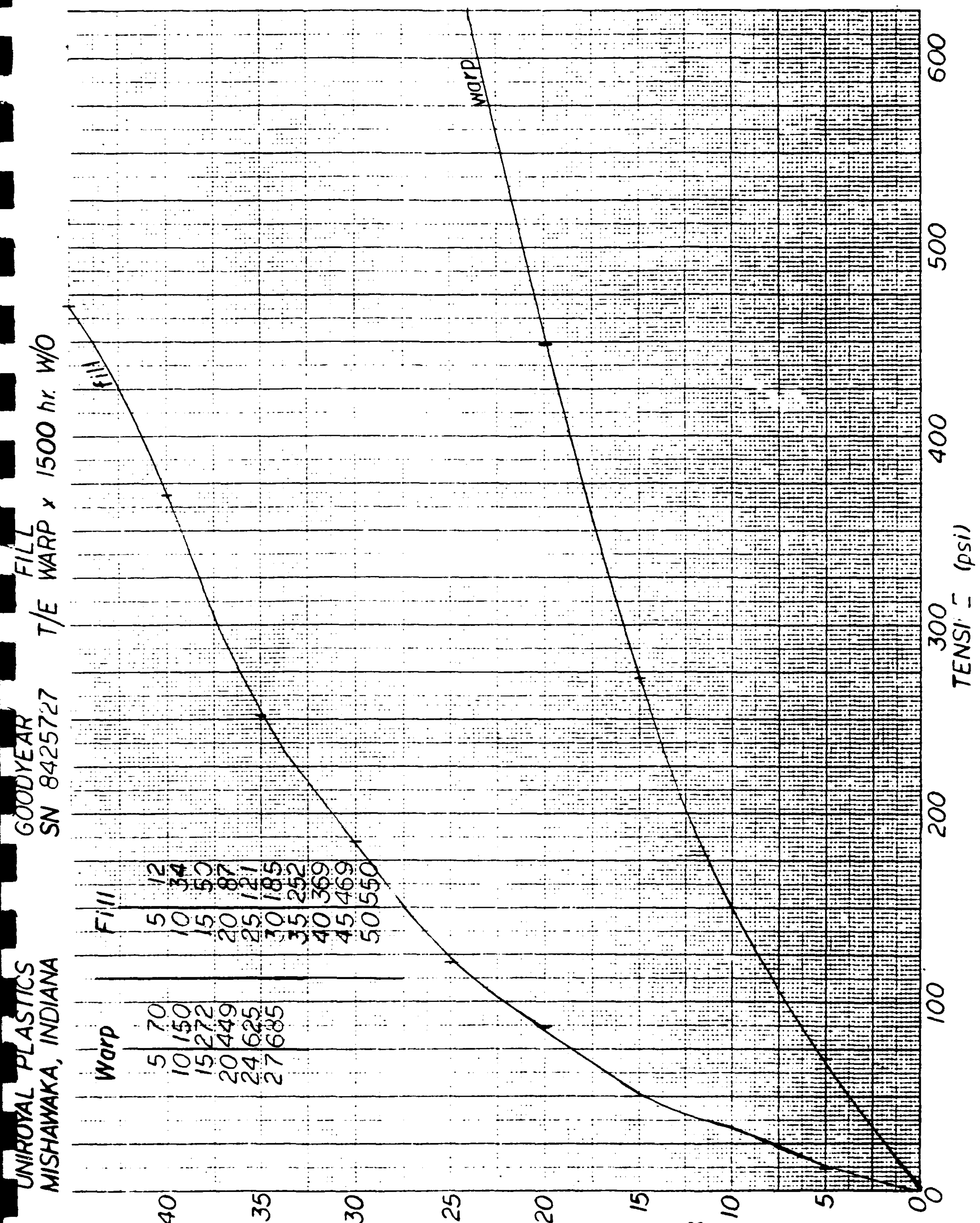
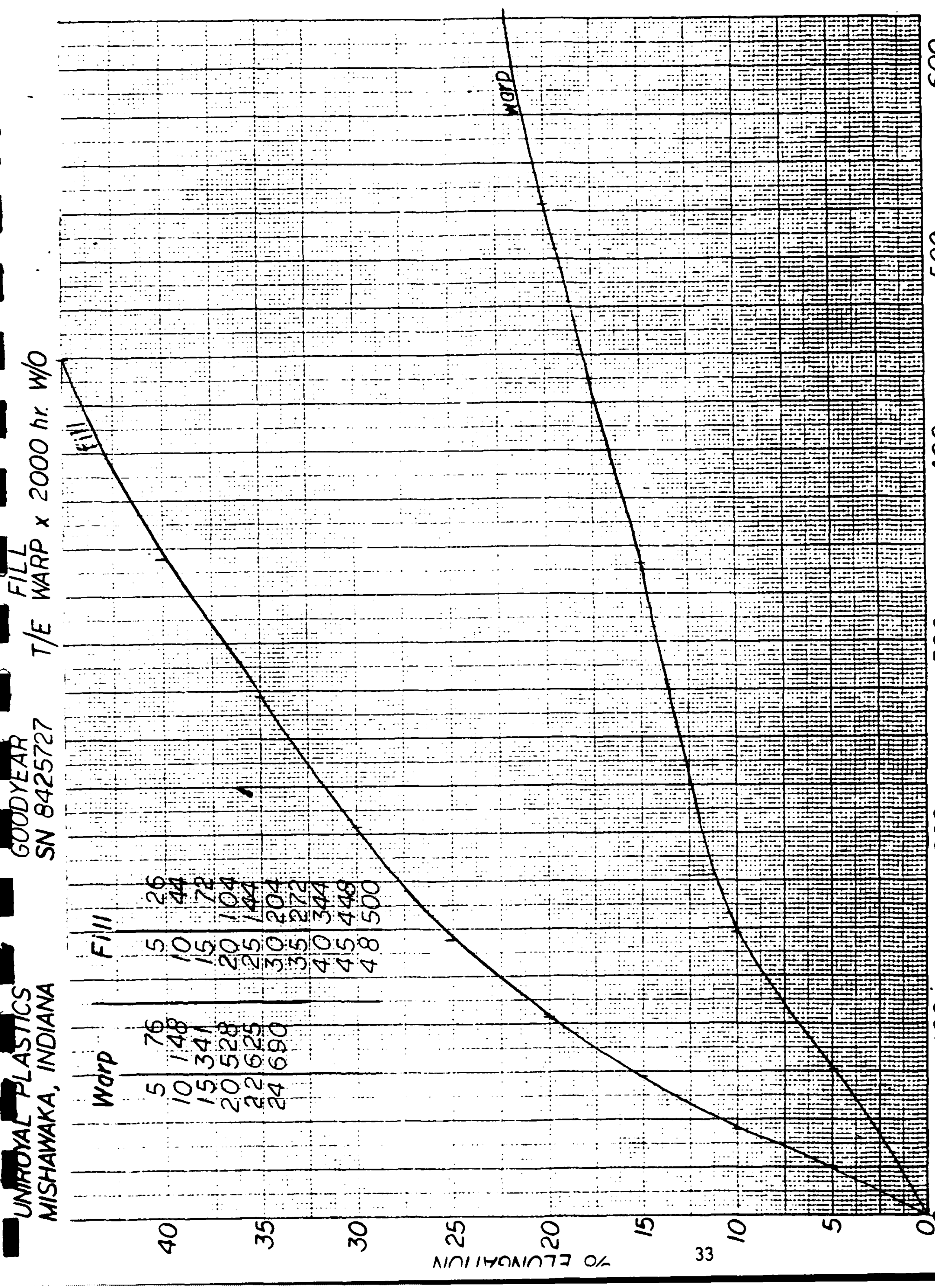
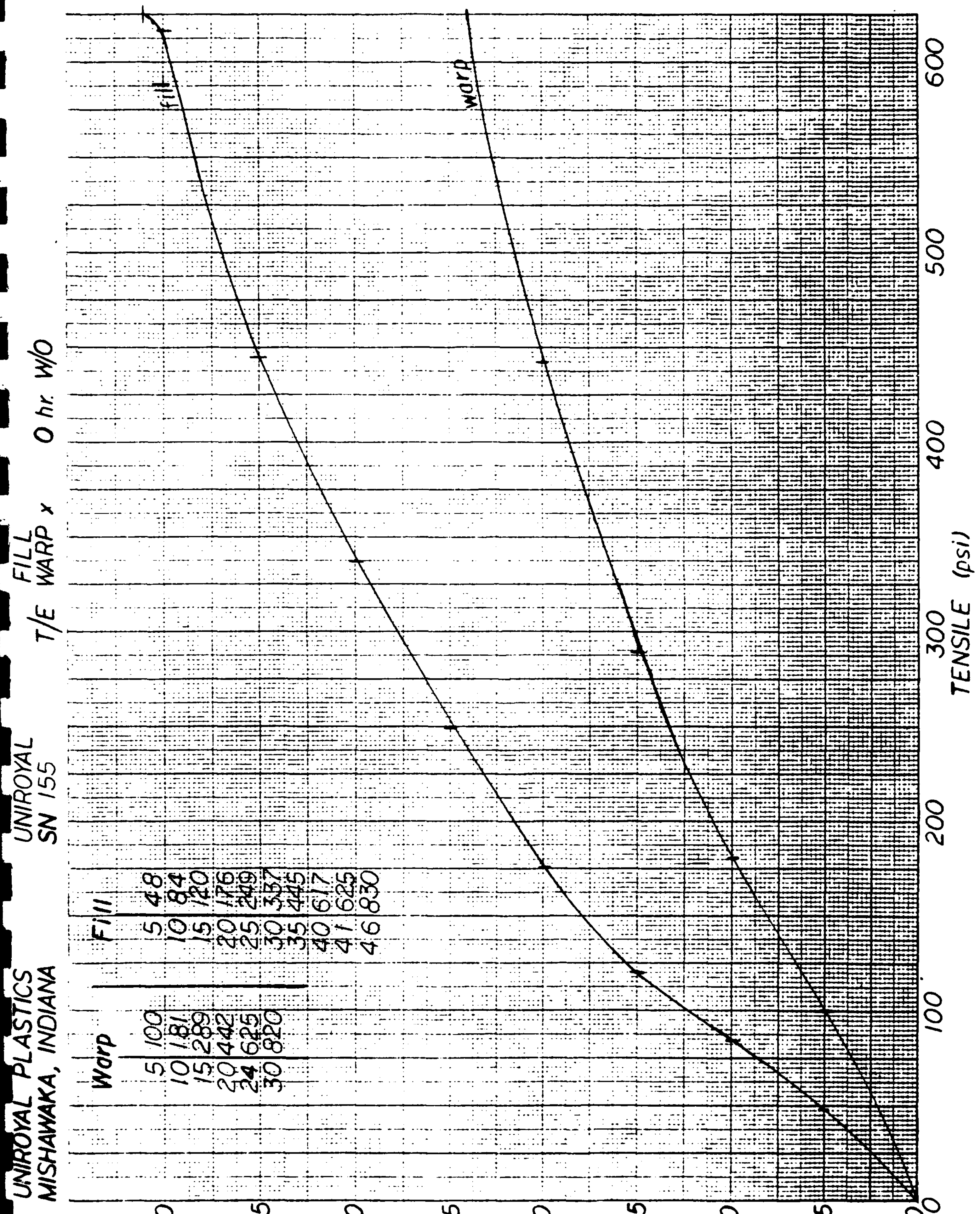

UNIROYAL PLASTICS
MISHAWAKA, INDIANA
GOODYEAR
SN 8425727
FILL
T/E WARP x 1500 hr. W/O
Warp
5 70
10 150
15 272
20 449
24 625
27 685
Fill
5 12
10 34
15 50
20 87
25 121
30 185
35 252
40 369
45 469
50 550
fill
warp
0 5 10 15 20 25 30 35 40
0 100 200 300 400 500 600
TENSI_ (psi)

FIGURE 13



UNIROYAL PLASTICS
MISHAWAKA, INDIANA
GOODYEAR
SN 8425727
FILL
T/E WARP x 2000 hr. W/O
Warp
5 76
10 148
15 341
20 528
22 625
24 690
Fill
5 26
10 44
15 72
20 104
25 144
30 204
35 272
40 344
45 448
48 500
warp
fill
0 100 200 300 400 500 600
TENSILE (psi)
0 5 10 15 20 25 30 35 40
% ELONGATION

FIGURE 14



UNIROYAL PLASTICS
MISHAWAKA, INDIANA
UNIROYAL
SN 155
T/E
FILL
WARP x
0 hr. W/O
Warp
5 100
10 181
15 289
20 442
24 625
30 820
Fill
5 48
10 84
15 120
20 176
25 249
30 337
35 445
40 617
41 625
46 830
fill
warp
TENSILE (psi)
0
100
200
300
400
500
600
% ELONGATION
0
5
10
15
20
25
30
35
40

FIGURE 15

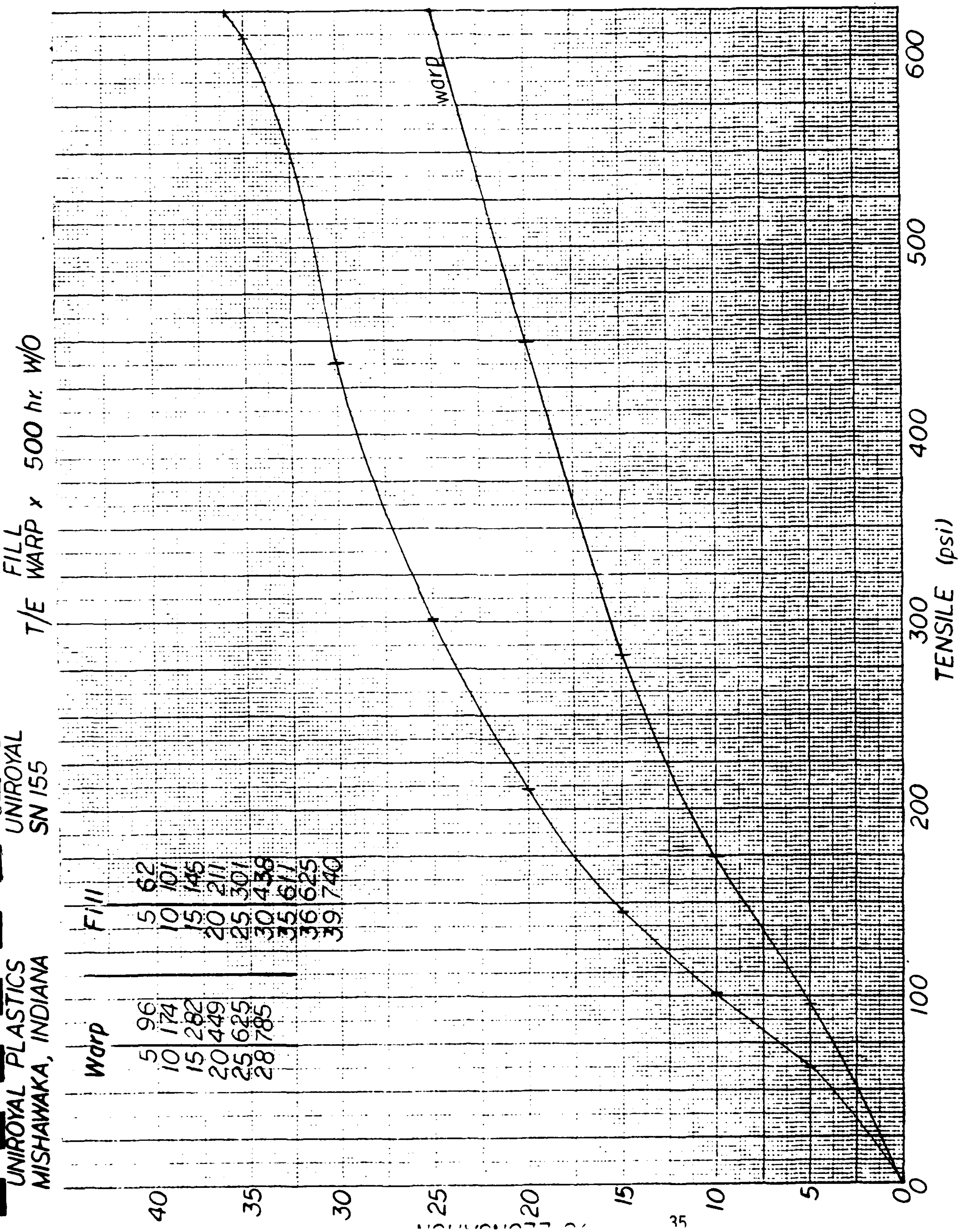

UNIROYAL PLASTICS
MISHAWAKA, INDIANA
UNIROYAL
SN 155
FILL
T/E WARP x 500 hr. W/O
Warp
5 96
10 174
15 282
20 449
25 625
28 785
Fill
5 62
10 101
15 145
20 211
25 301
30 438
35 611
36 625
39 740
warp
TENSILE (psi)
0
100
200
300
400
500
600
0
5
10
15
20
25
30
35
40

FIGURE 16

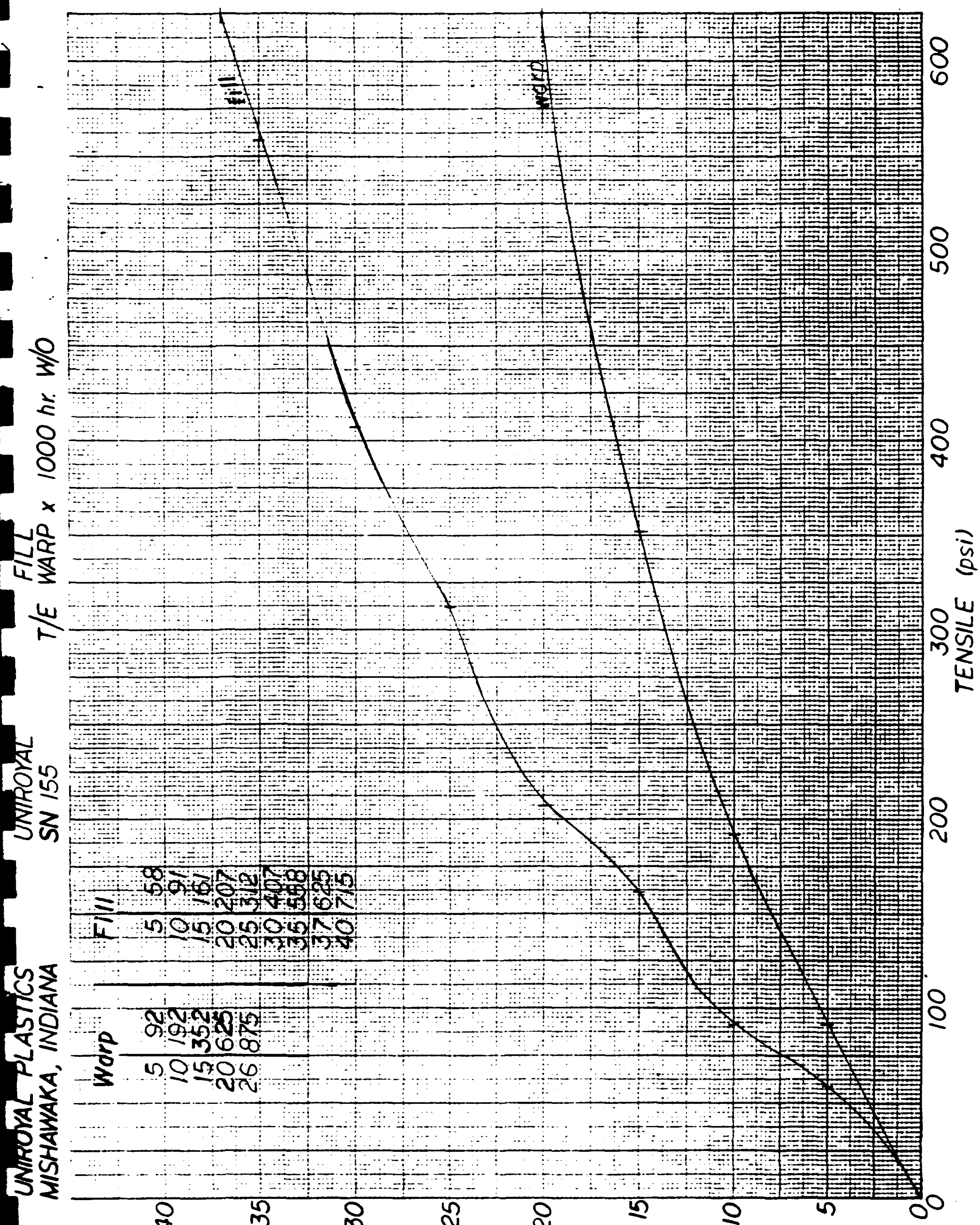

UNIROYAL PLASTICS
MISHAWAKA, INDIANA
UNIROYAL
SN 155
FILL
T/E WARP x 1000 hr. W/O
Warp
5 92
10 192
15 352
20 625
26 875
Fill
5 58
10 91
15 161
20 207
25 312
30 407
35 568
37 625
40 715
Fill
Warp
0 100 200 300 400 500 600
TENSILE (psi)
0 5 10 15 20 25 30 35 40
% ELONGATION

FIGURE 17

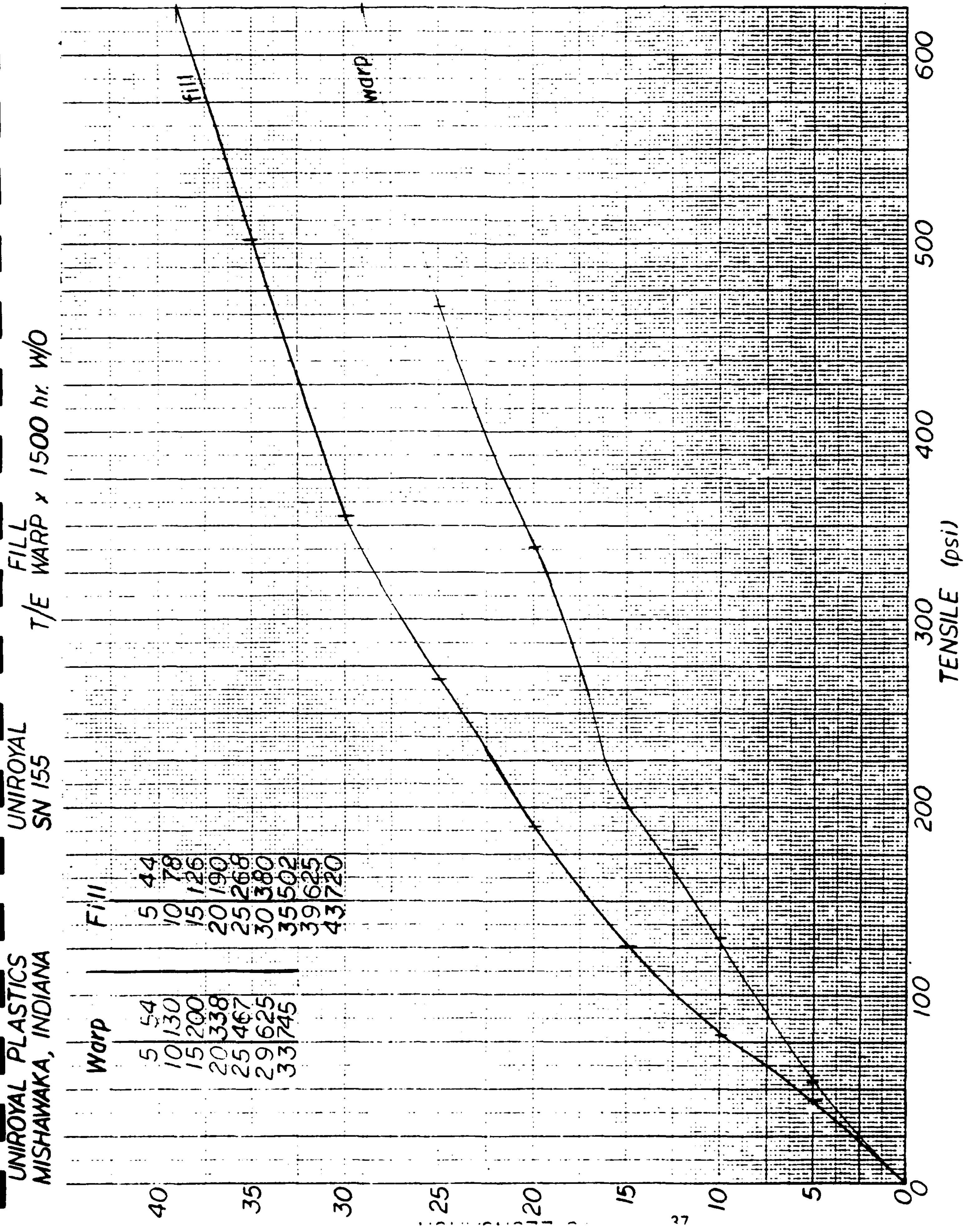

UNIROYAL PLASTICS
MISHAWAKA, INDIANA
UNIROYAL
SN 155
T/E FILL WARP x 1500 hr. W/O
Warp
5 54
10 130
15 200
20 338
25 467
29 625
33 745
Fill
5 44
10 78
15 126
20 190
25 268
30 380
35 502
39 625
43 720
fill
warp
TENSILE (psi)
0
100
200
300
400
500
600
0
5
10
15
20
25
30
35
40

FIGURE 18

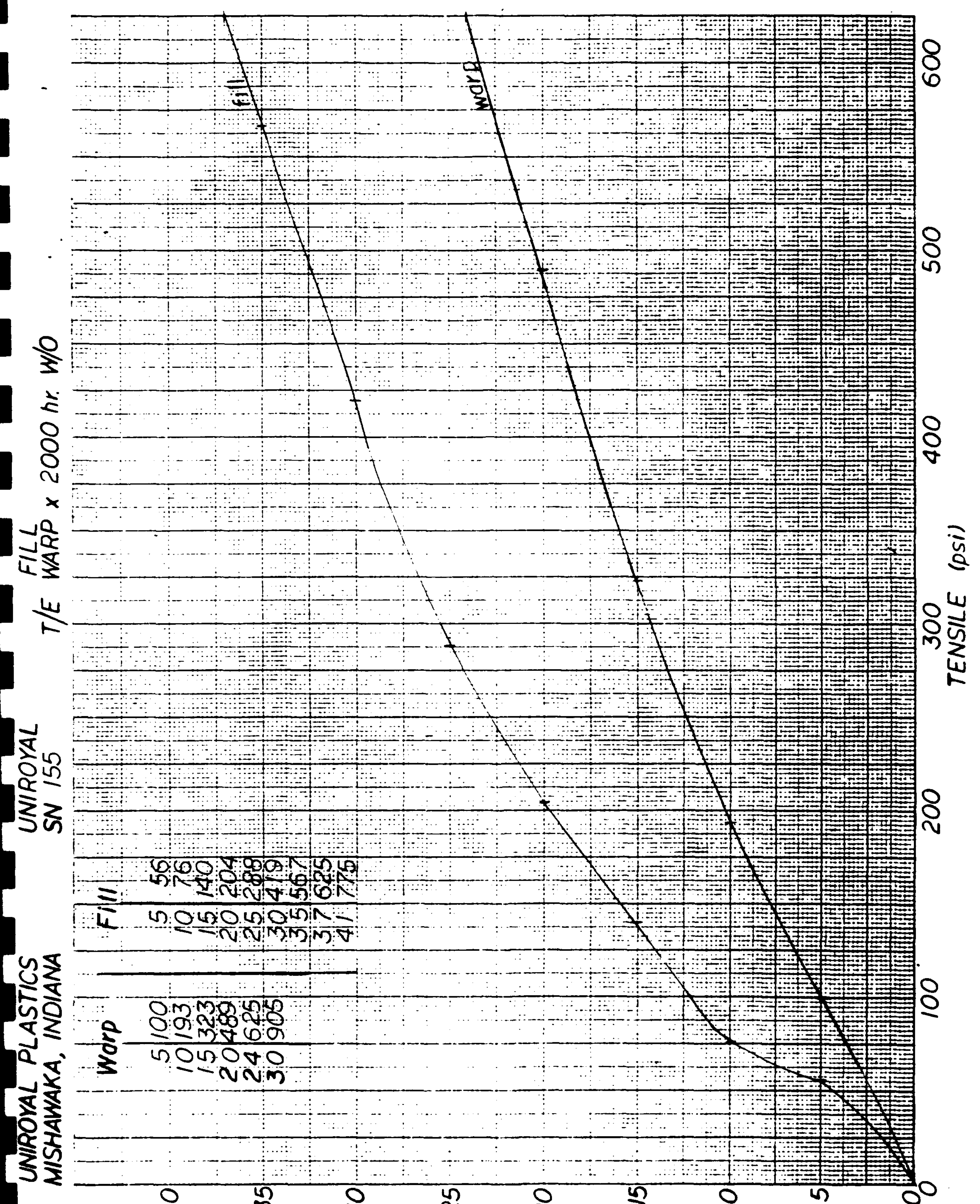
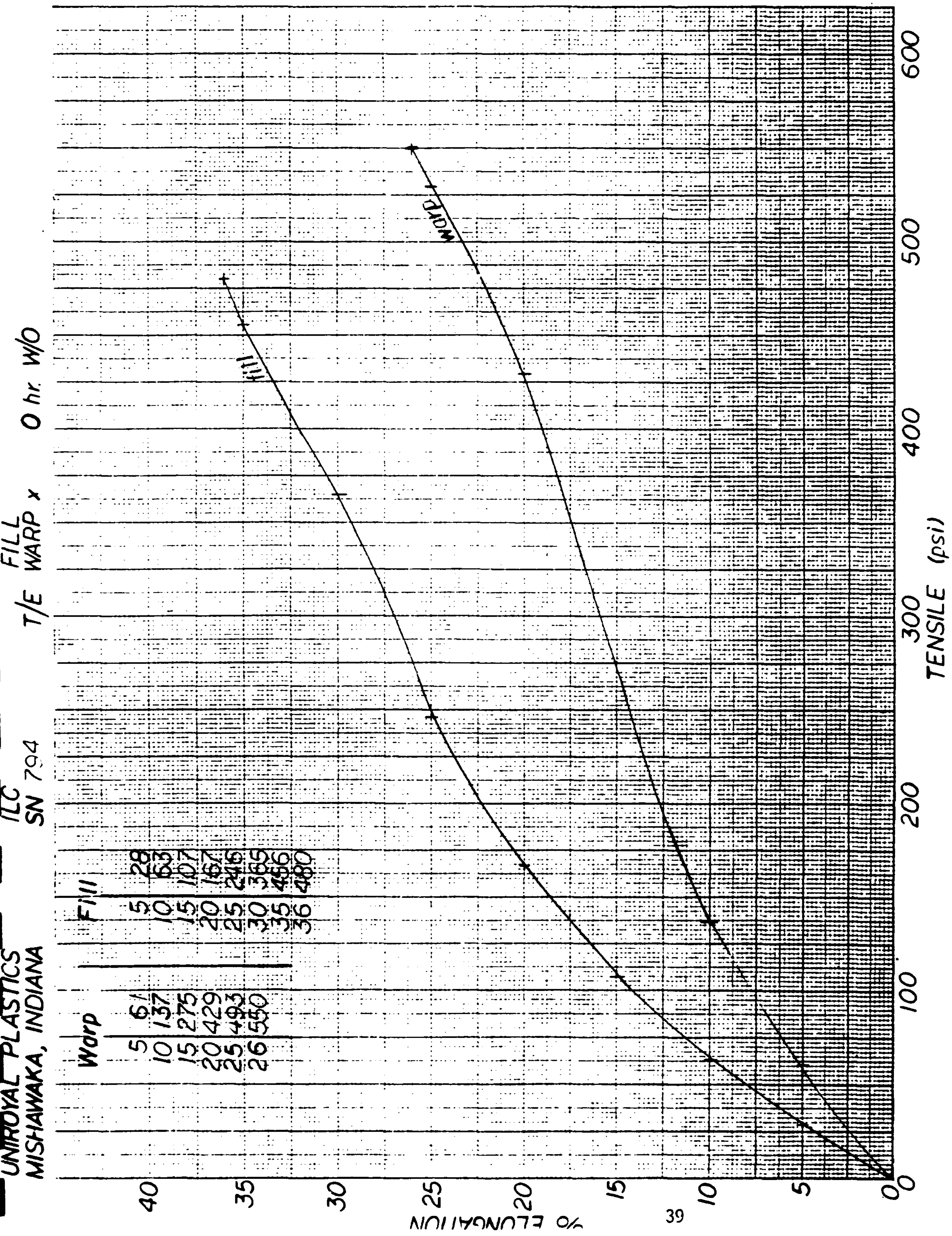

UNIROYAL PLASTICS
MISHAWAKA, INDIANA
UNIROYAL
SN 155
T/E FILL
WARP x 2000 hr. W/O
Warp
5 100
10 193
15 323
20 489
24 625
30 905
Fill
5 56
10 76
15 140
20 204
25 288
30 479
35 567
37 625
41 775
fill
warp
0
100
200
300
400
500
600
TENSILE (psi)
0
5
10
15
20
25
30
35
40
% ELONGATION

FIGURE 19



UNIROYAL PLASTICS
MISHAWAKA, INDIANA
ILC
SN 794
T/E
FILL
WARP x
0 hr. W/O
Warp
5 61
10 137
15 275
20 429
25 493
26 550
Fill
5 28
10 63
15 107
20 167
25 246
30 365
35 456
36 480
fill
warp
0
100
200
300
400
500
600
TENSILE (psi)
0
5
10
15
20
25
30
35
40
% ELONGATION

FIGURE 20

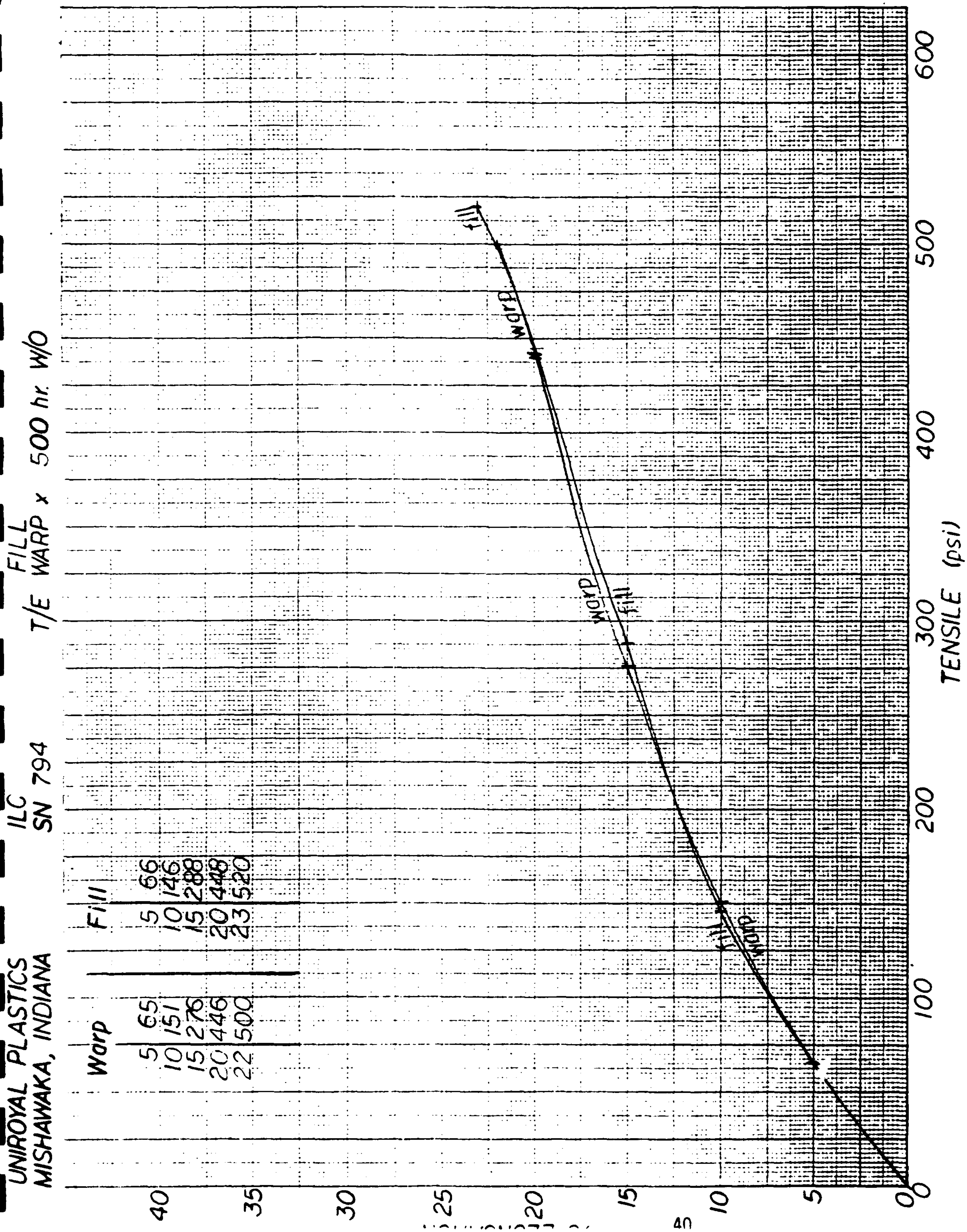

UNIROYAL PLASTICS
MISHAWAKA, INDIANA
ILC
SN 794
T/E FILL
WARP x 500 hr. W/O
Warp
5 65
10 151
15 276
20 446
22 500
Fill
5 66
10 146
15 288
20 448
23 520
warp
fill
TENSILE (psi)
0 100 200 300 400 500 600
0 5 10 15 20 25 30 35 40

FIGURE 21

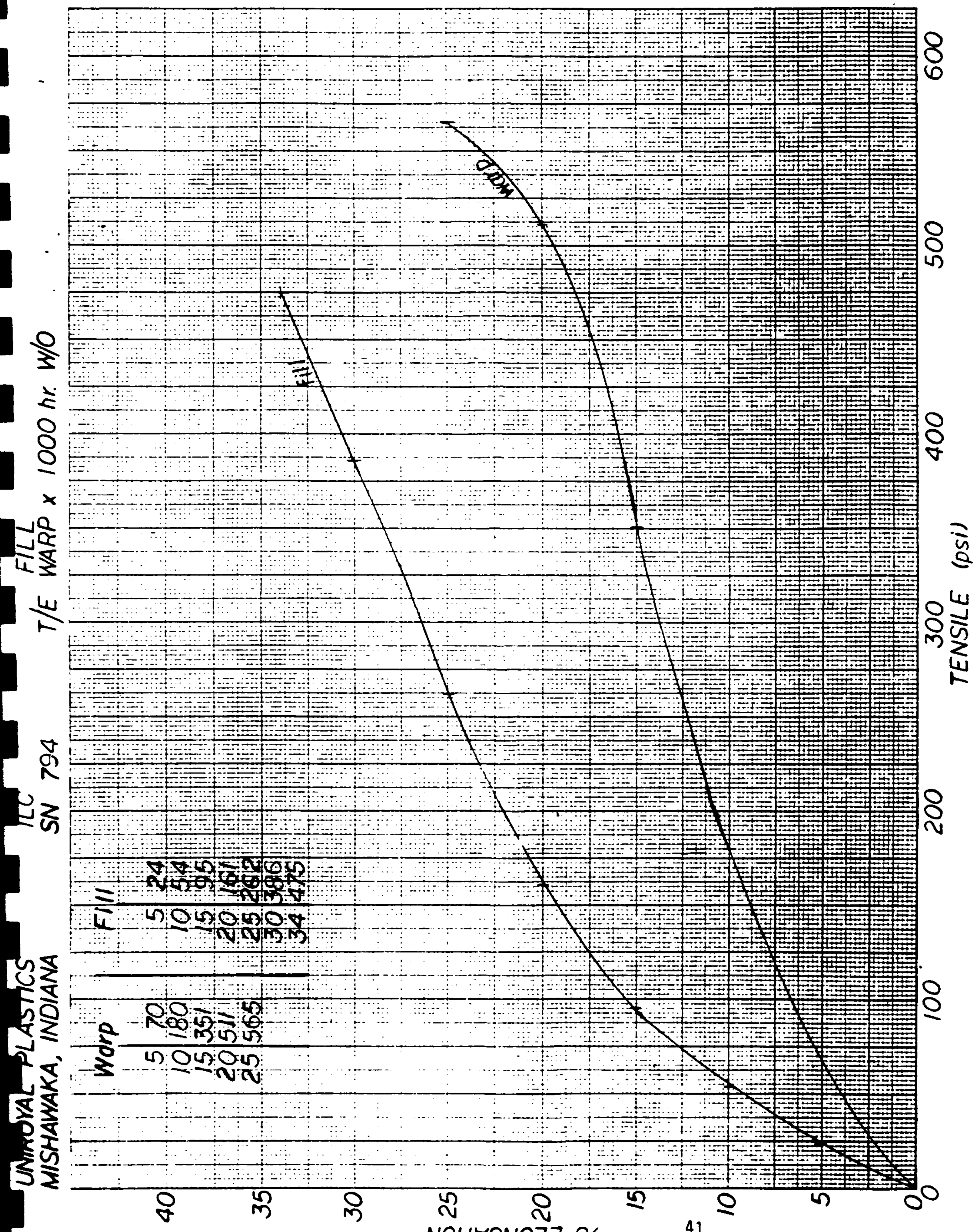
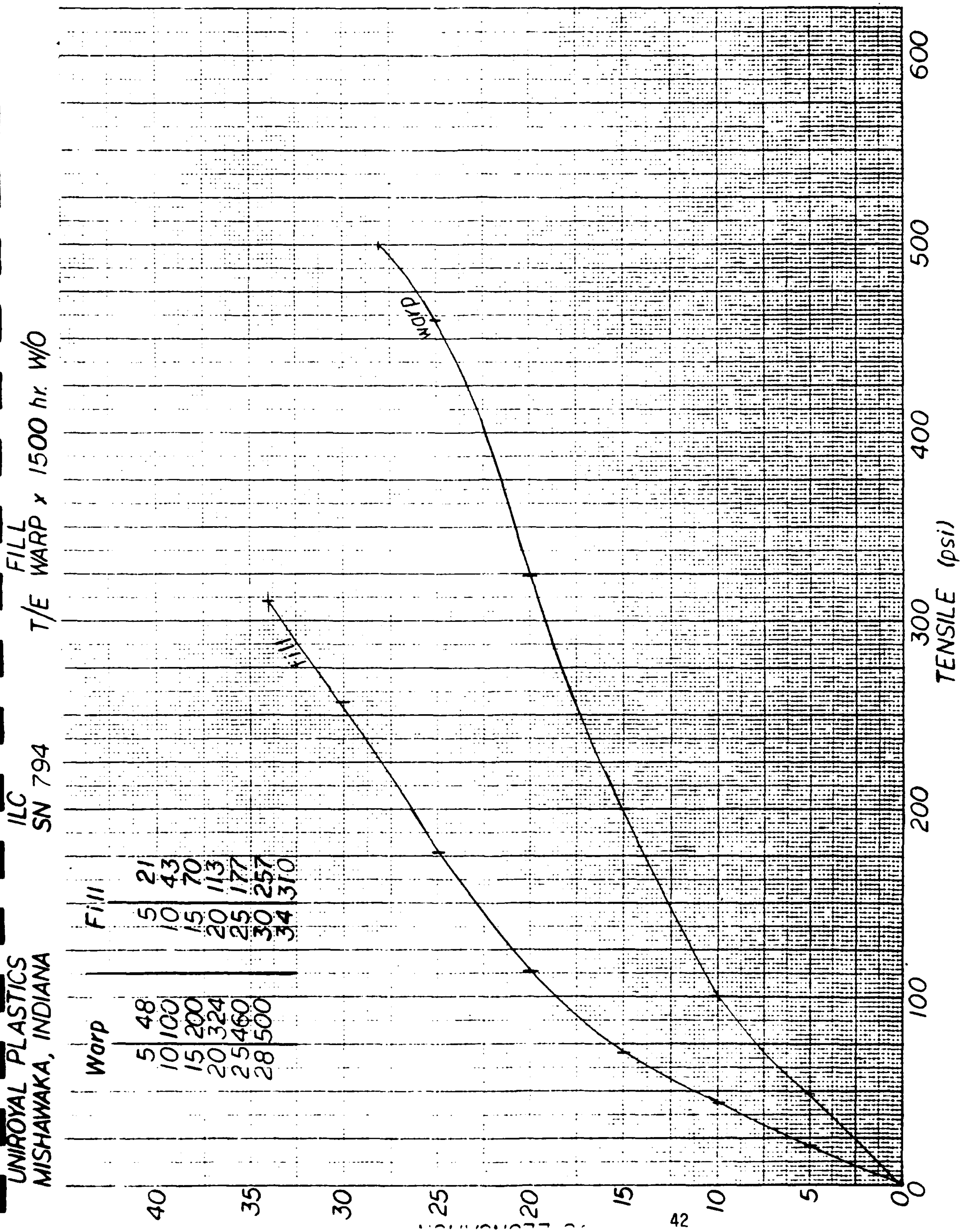
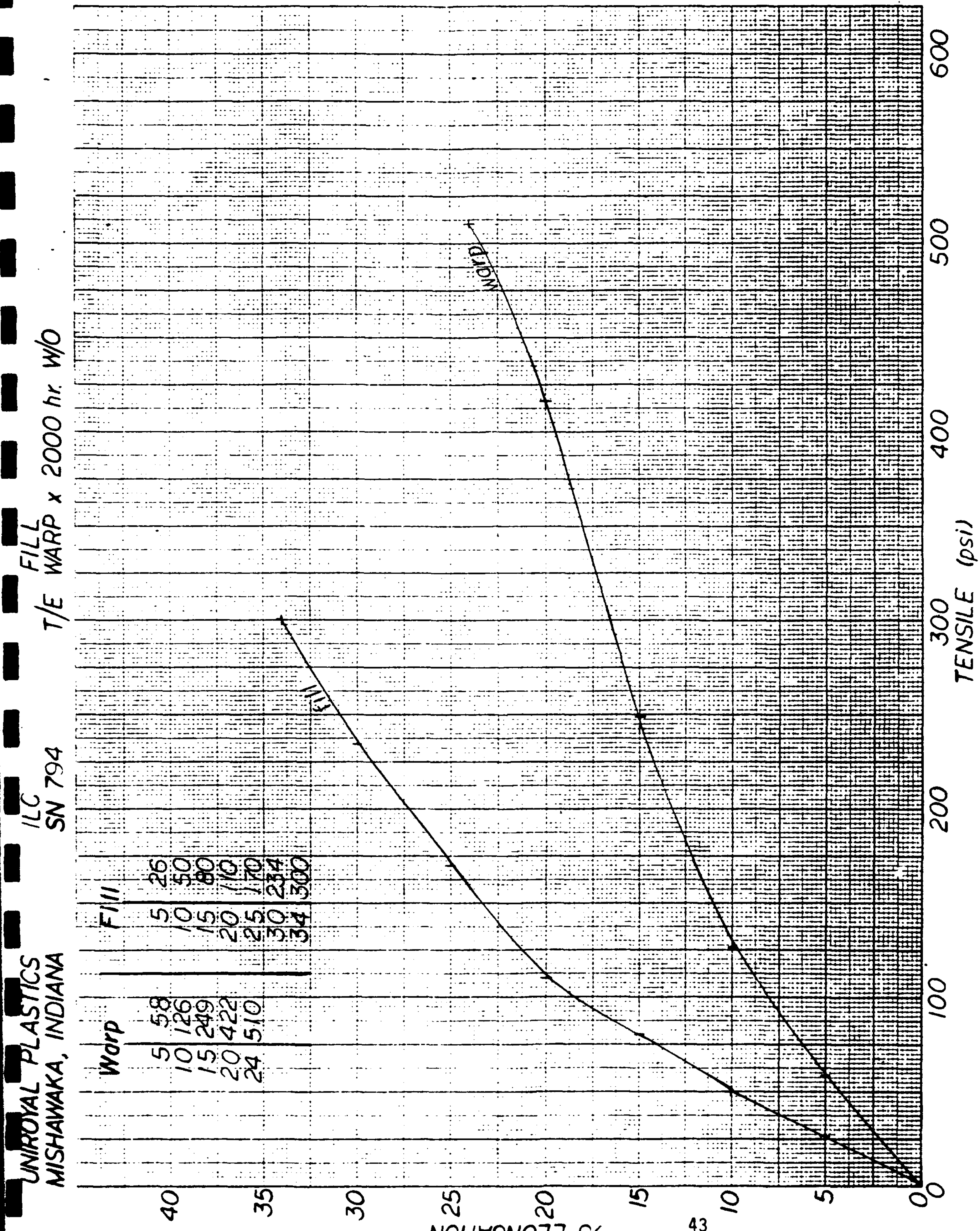

UNIROYAL PLASTICS
MISHAWAKA, INDIANA
ILC
SN 794
FILL
T/E WARP x 1000 hr. W/O
Warp
5 70
10 180
15 351
20 511
25 565
Fill
5 24
10 54
15 95
20 161
25 262
30 386
34 475
Warp
Fill
TENSILE (psi)
% ELONGATION
0
100
200
300
400
500
600
5
10
15
20
25
30
35
40

FIGURE 22



UNIROYAL PLASTICS
MISHAWAKA, INDIANA
ILC
SN 794
T/E FILL
WARP x 1500 hr. W/O
TENSILE (psi)
Warp
5 48
10 100
15 200
20 324
25 460
28 500
Fill
5 21
10 43
15 70
20 113
25 177
30 257
34 310
warp
fill

FIGURE 23



UNIROYAL PLASTICS
MISHAWAKA, INDIANA
ILC
SN 794
FILL
T/E WARP x 2000 hr. W/O
Warp
5 58
10 126
15 249
20 422
24 510
Fill
5 26
10 50
15 80
20 110
25 170
30 234
34 300
Warp
Fill
TENSILE (psi)
% ELONGATION
0 100 200 300 400 500 600
0 5 10 15 20 25 30 35 40

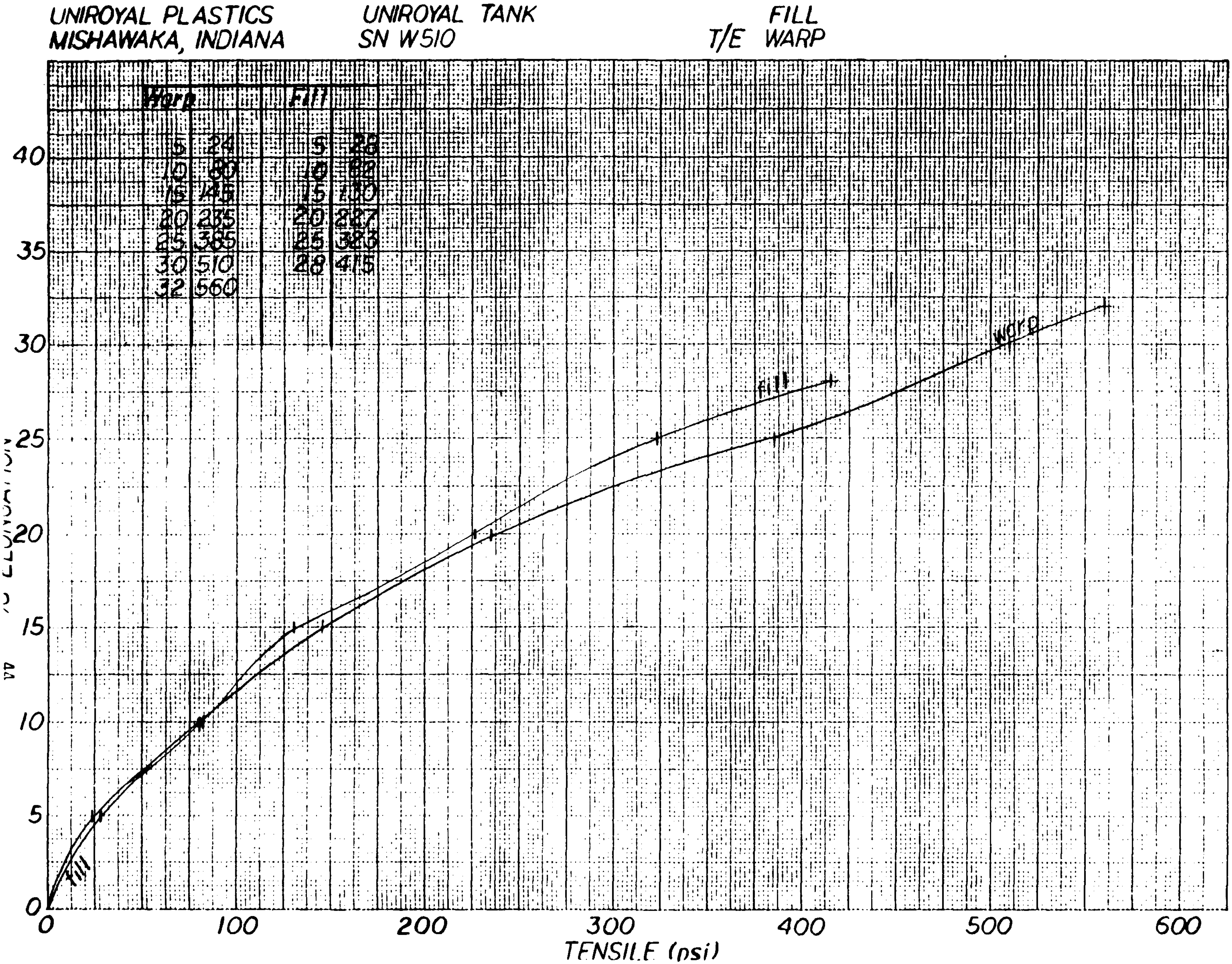
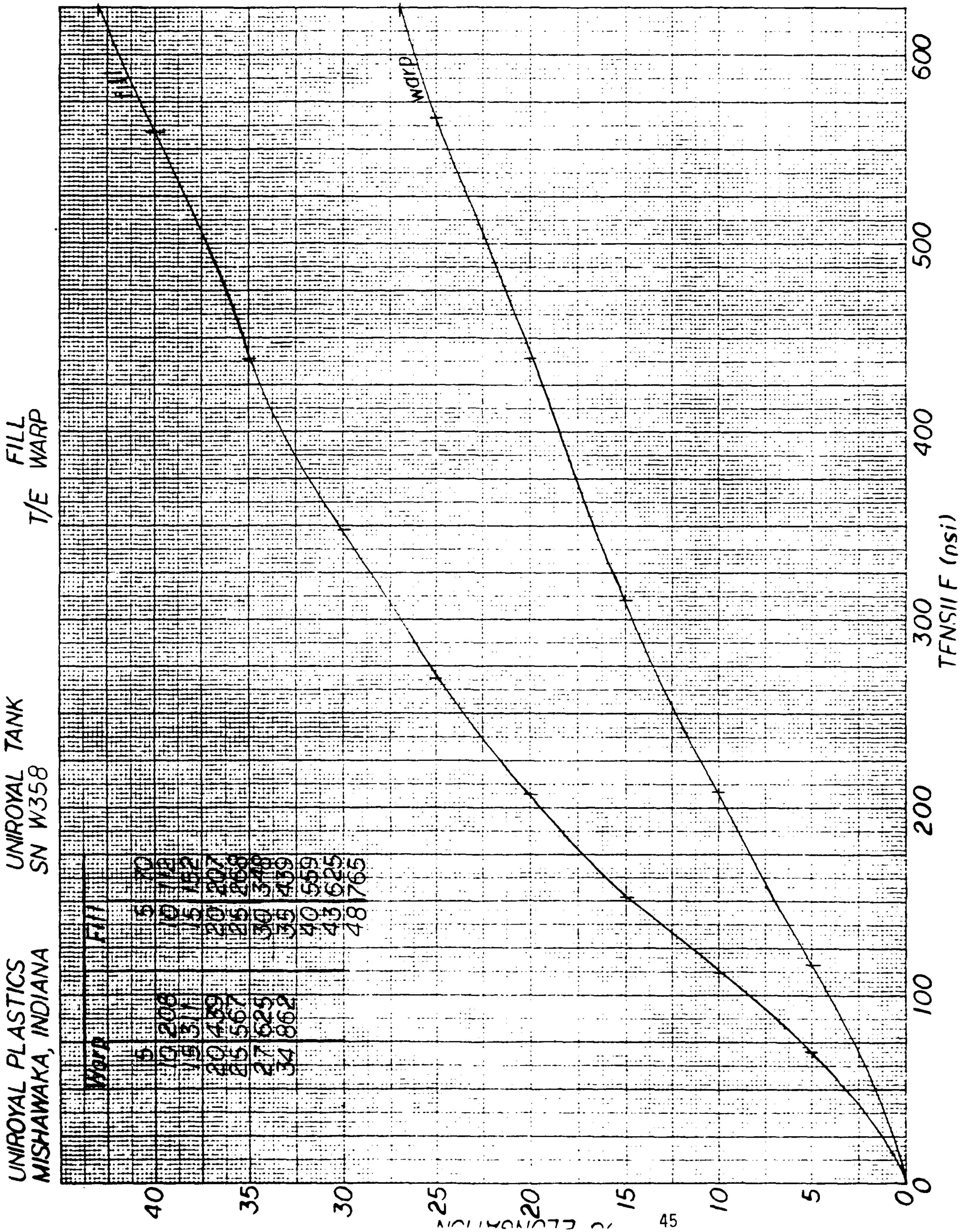

UNIROYAL PLASTICS
MISHAWAKA, INDIANA
UNIROYAL TANK
SN W510
T/E FILL WARP
Warp
5 24
10 80
15 145
20 235
25 385
30 510
32 560
Fill
5 28
10 82
15 130
20 227
25 323
28 415
Fill
Warp
TENSILE (psi)
0
100
200
300
400
500
600
5
10
15
20
25
30
35
40

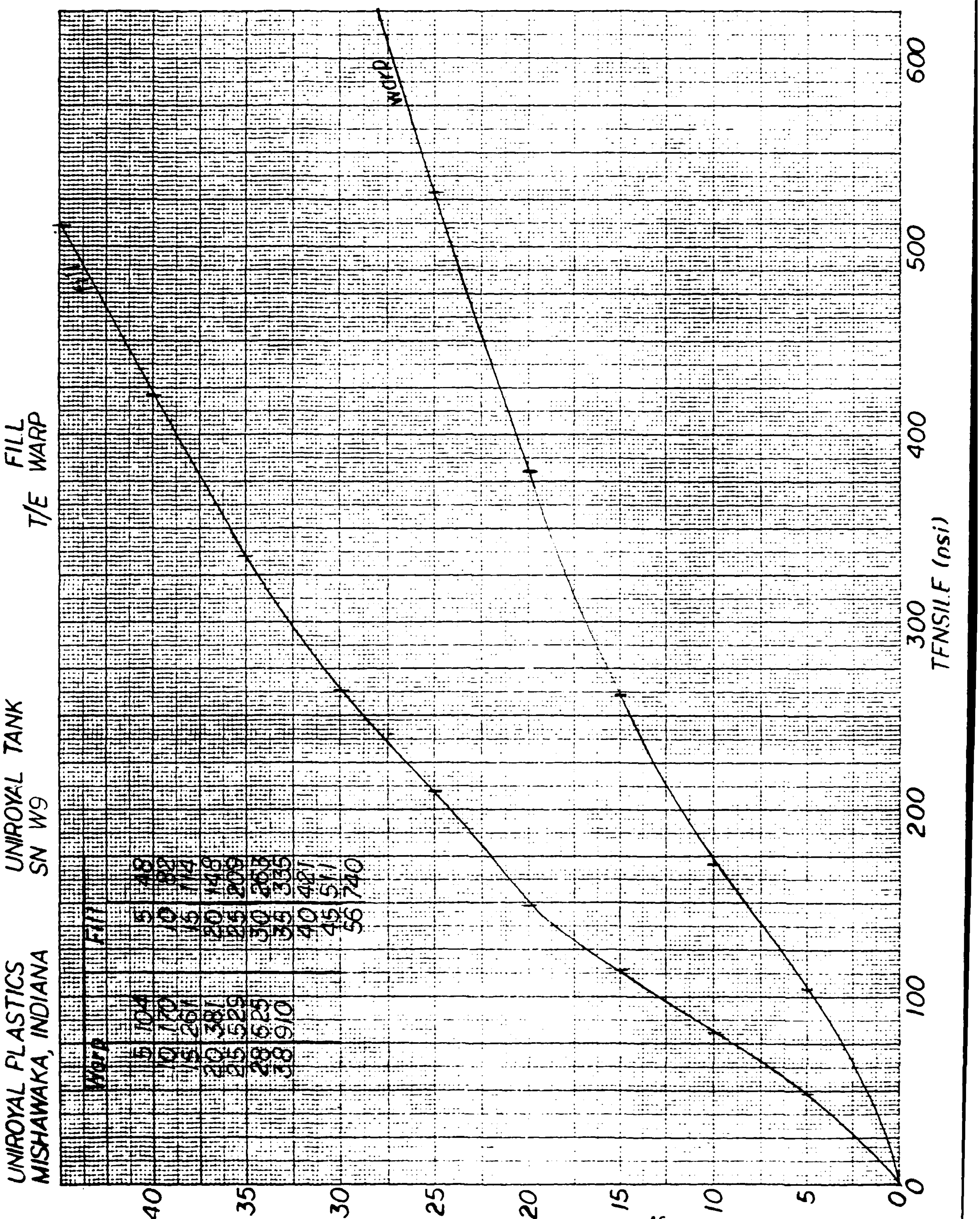
FIGURE 24

FIGURE 25



UNIROYAL PLASTICS
MISHAWAKA, INDIANA
UNIROYAL TANK
SN W358
T/E FILL
WARP
Warp
5
10 208
15 317
20 438
25 567
27 625
34 862
Fill
5 70
10 112
15 152
20 207
25 268
30 348
35 439
40 559
43 625
48 765
Fill
warp
TENSILE (psi)
0
100
200
300
400
500
600
% ELONGATION
0
5
10
15
20
25
30
35
40

FIGURE 26



UNIROYAL PLASTICS
MISHAWAKA, INDIANA
UNIROYAL TANK
SN W9
T/E
FILL
WARP
Warp
5 104
10 170
15 261
20 381
25 529
28 625
38 910
Fill
5 48
10 82
15 114
20 148
25 209
30 263
35 335
40 427
45 511
56 740
warp
fill
0
100
200
300
400
500
600
TENSILE (psi)
0
5
10
15
20
25
30
35
40
% ELONGATION

FIGURE 27

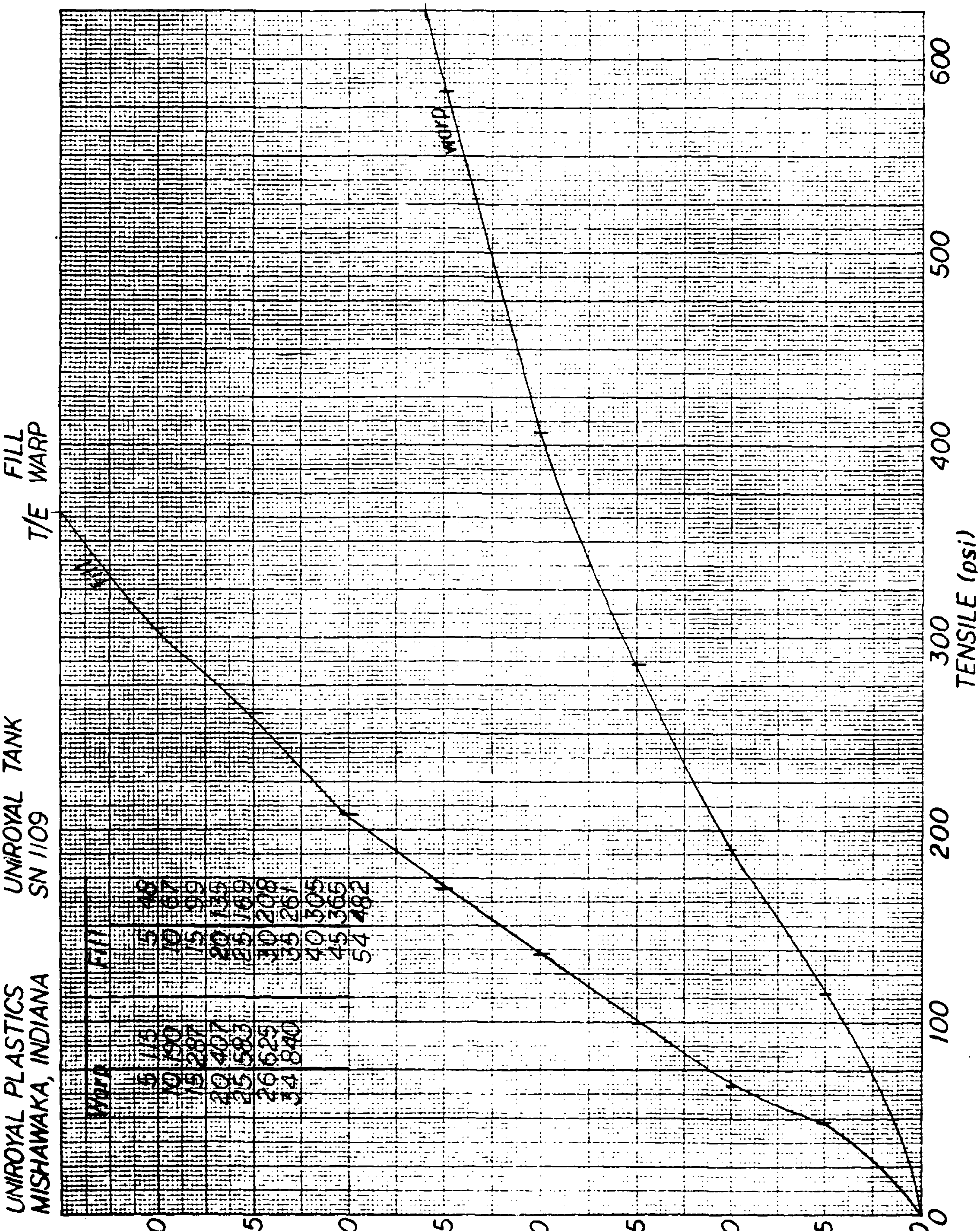
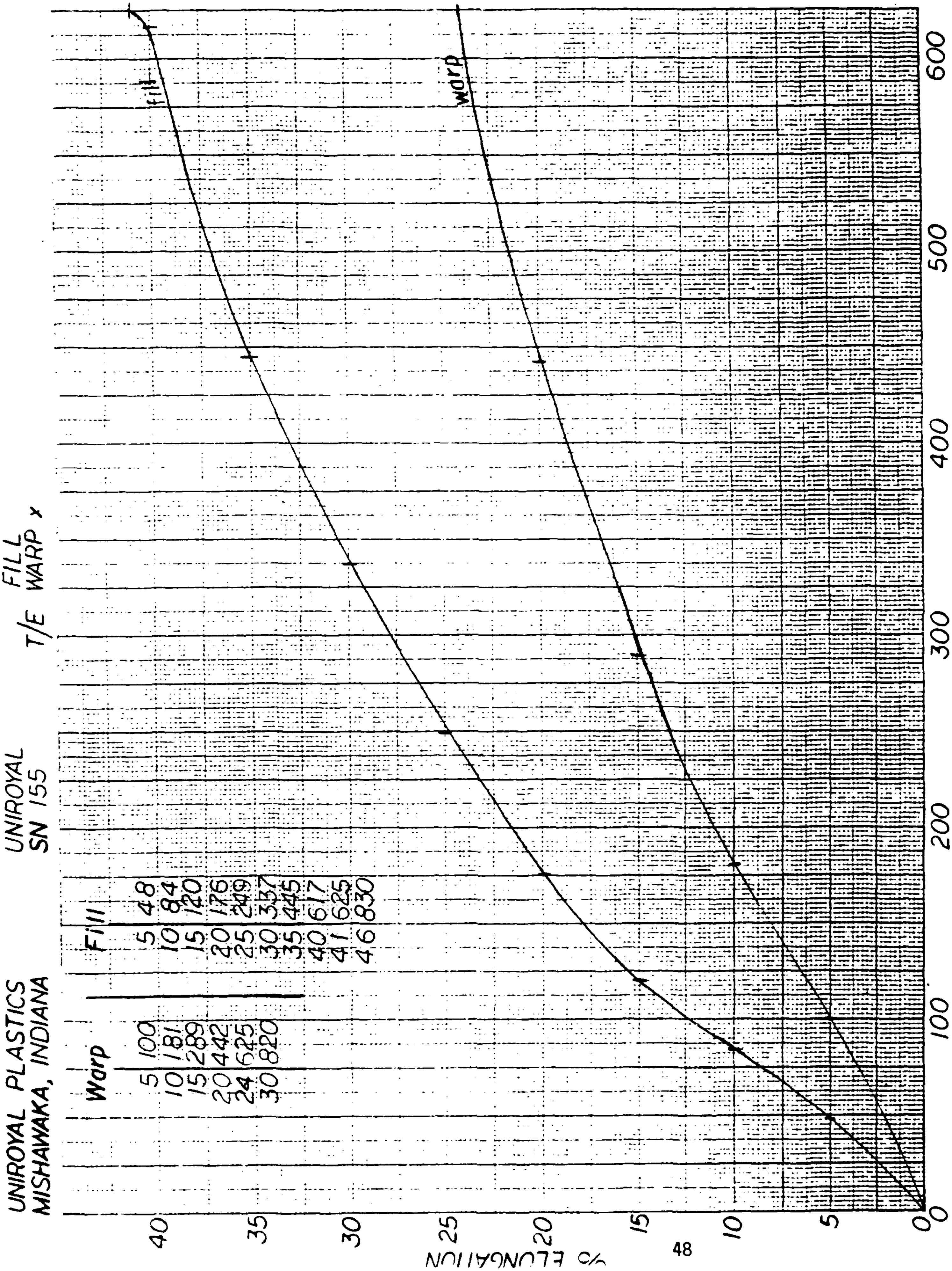

UNIROYAL PLASTICS
MISHAWAKA, INDIANA
UNIROYAL TANK
SN 1109
T/E
FILL
WARP
Warp
5 115
10 190
15 287
20 407
25 583
26 625
34 840
Fill
5 46
10 67
15 99
20 135
25 169
30 208
35 261
40 305
45 366
54 482
warp
TENSILE (psi)
0
100
200
300
400
500
600
5
10
15
20
25
30
35
40

FIGURE 28



UNIROYAL PLASTICS
MISHAWAKA, INDIANA
UNIROYAL
SN 155
T/E FILL
WARP x
Warp
5 100
10 181
15 289
20 442
24 625
30 820
Fill
5 48
10 84
15 120
20 176
25 249
30 337
35 445
40 617
41 625
46 830
fill
warp
0 5 10 15 20 25 30 35 40
% ELONGATION
0 100 200 300 400 500 600
TENSILE (psi)

FIGURE 29

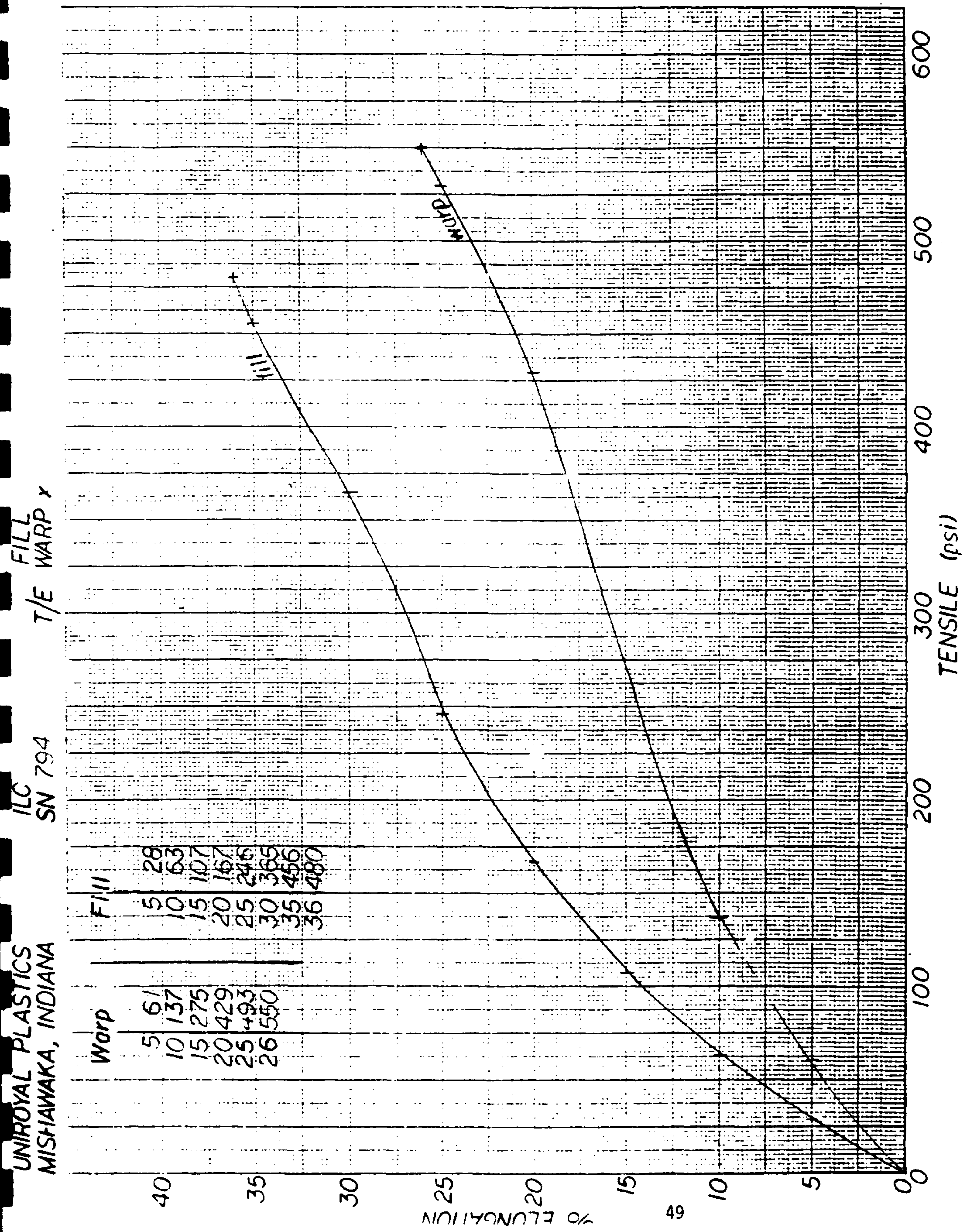

UNIROYAL PLASTICS
MISHAWAKA, INDIANA
ILC
SN 794
T/E FILL
WARP x
Warp
5 61
10 137
15 275
20 429
25 493
26 550
Fill
5 28
10 63
15 107
20 167
25 246
30 365
35 456
36 480
fill
warp
TENSILE (psi)
% ELONGATION
0
100
200
300
400
500
600
5
10
15
20
25
30
35
40

FIGURE 30

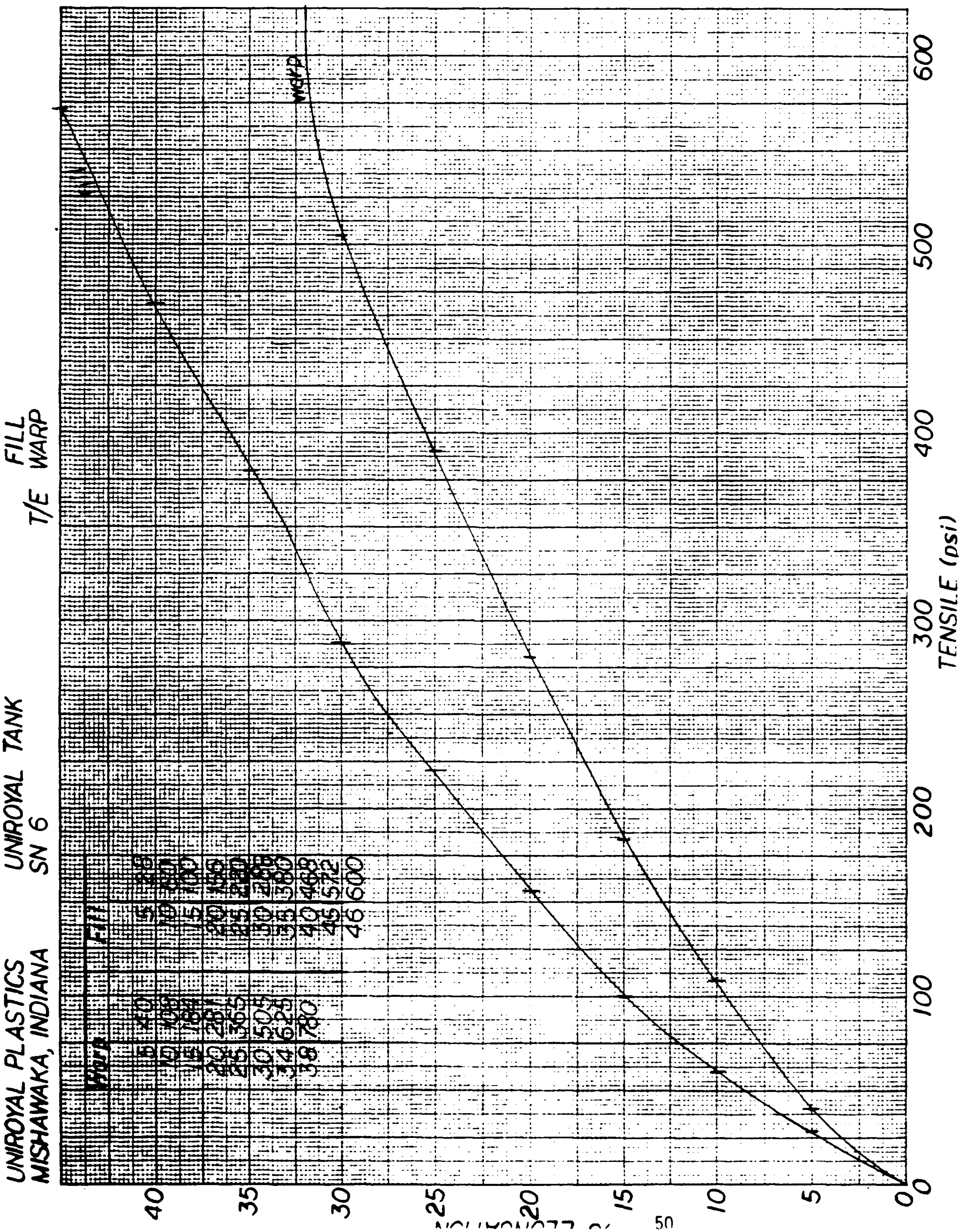
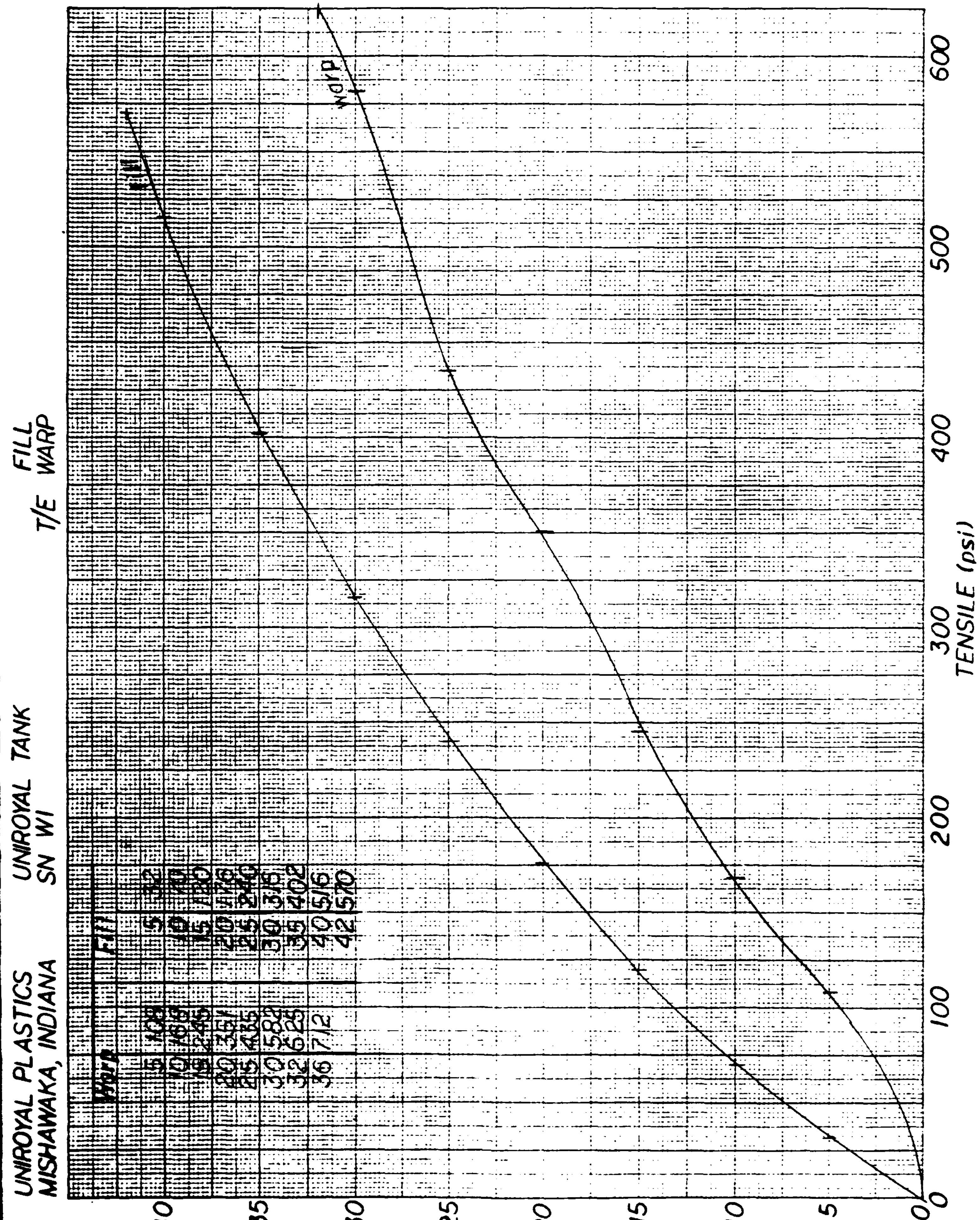

UNIROYAL PLASTICS
MISHAWAKA, INDIANA
UNIROYAL TANK
SN 6
T/E FILL
WARP
Warp
5 40
10 106
15 184
20 287
25 365
30 505
34 625
38 780
Fill
5 26
10 60
15 100
20 156
25 220
30 288
35 380
40 468
45 572
46 600
FILL
WARP
0
100
200
300
400
500
600
TENSILE (psi)
0
5
10
15
20
25
30
35
40
% ELONGATION

FIGURE 31



UNIROYAL PLASTICS
MISHAWAKA, INDIANA
UNIROYAL TANK
SN WI
T/E
FILL
WARP
Warp
5 108
10 168
15 245
20 351
25 435
30 582
32 625
36 712
Fill
5 32
10 70
15 120
20 176
25 240
30 316
35 402
40 516
42 570
Fill
Warp
TENSILE (psi)
0
100
200
300
400
500
600
0
5
10
15
20
25
30
35
40

FIGURE 32

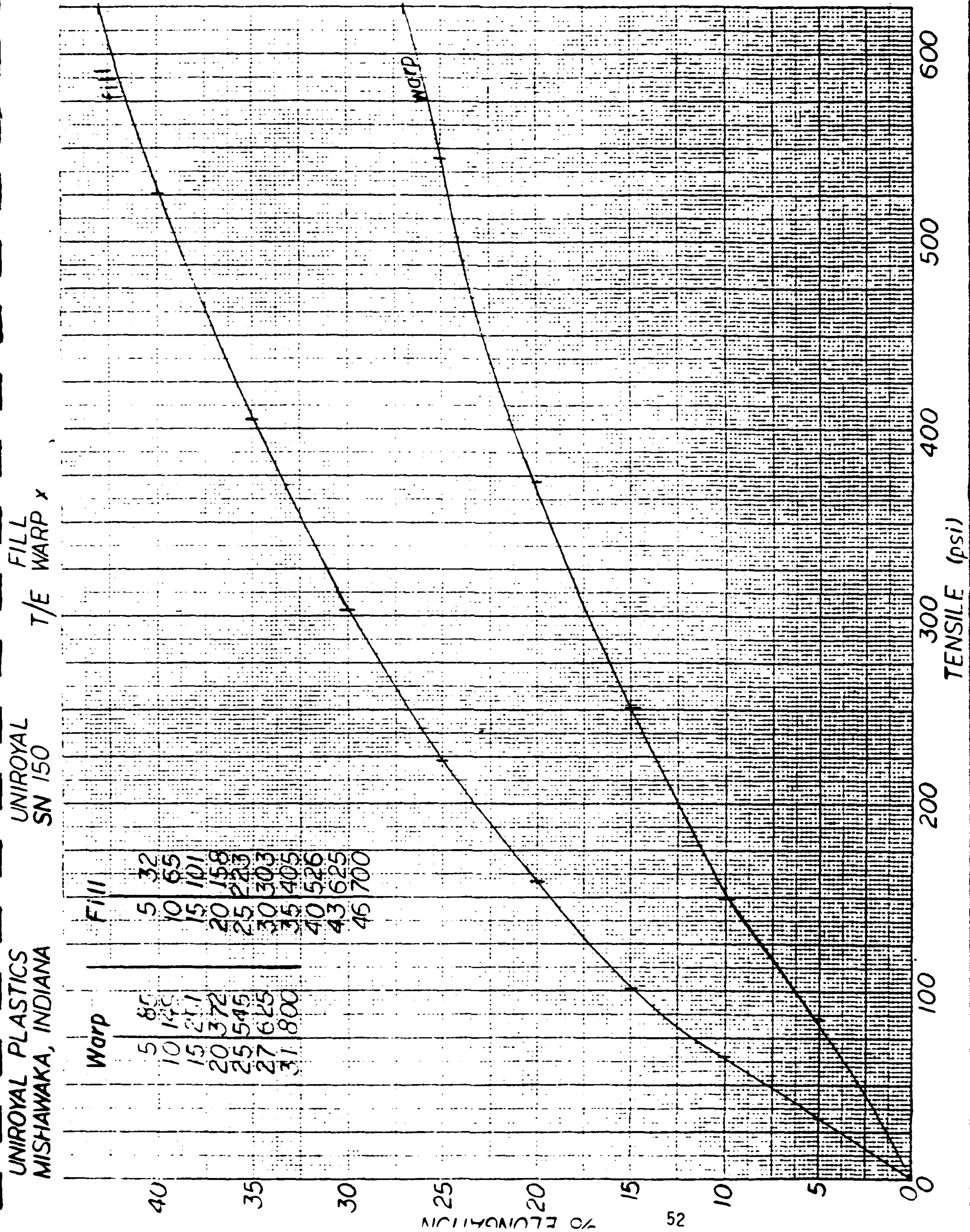
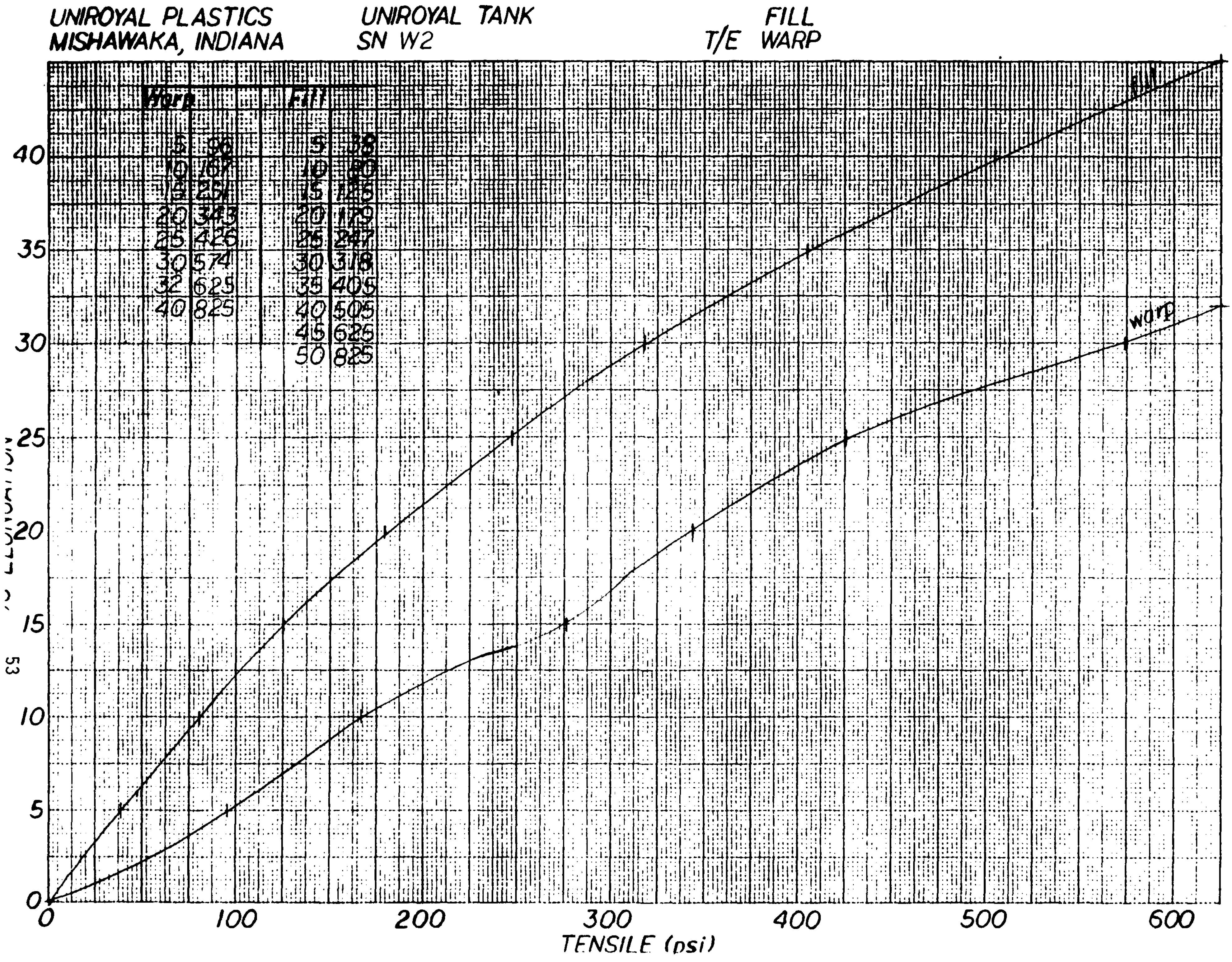

UNIROYAL PLASTICS
MISHAWAKA, INDIANA
UNIROYAL
SN 150
T/E FILL
WARP x
Warp
5 85
20 372
25 545
27 625
31 800
Fill
5 32
10 65
15 101
20 158
25 223
30 303
35 405
40 526
43 625
46 700
fill
warp
TENSILE (psi)
% ELONGATION
0
100
200
300
400
500
600
5
10
15
20
25
30
35
40

FIGURE 33


UNIROYAL PLASTICS
MISHAWAKA, INDIANA
UNIROYAL TANK
SN W2
FILL
T/E WARP
Warp
5 96
10 167
15 251
20 343
25 426
30 574
32 625
40 825
Fill
5 38
10 80
15 125
20 179
25 247
30 318
35 405
40 505
45 625
50 825
fill
warp
0
5
10
15
20
25
30
35
40
0
100
200
300
400
500
600
TENSILE (psi)

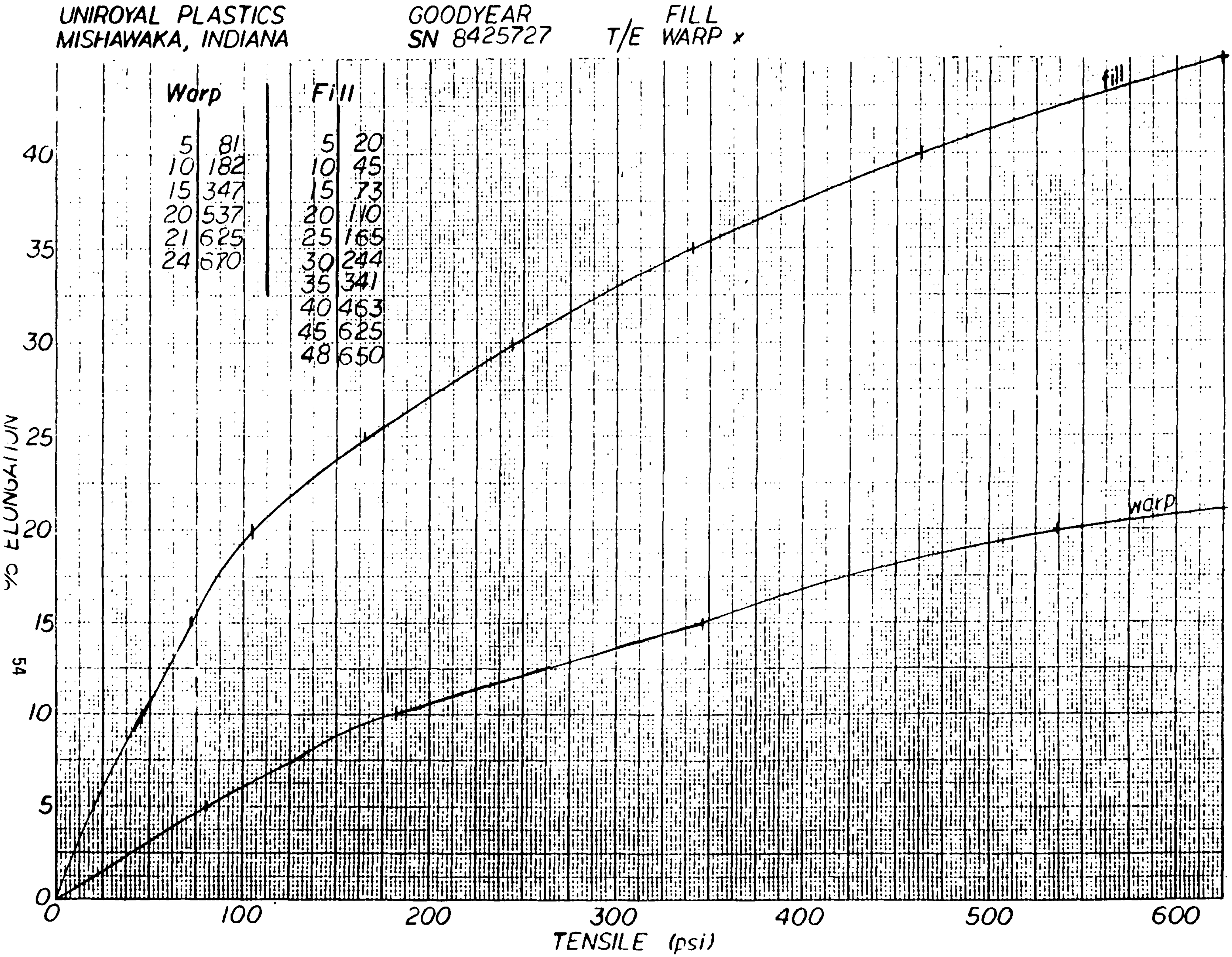

UNIROYAL PLASTICS
MISHAWAKA, INDIANA
GOODYEAR
SN 8425727
T/E
FILL
WARP x
Warp
5 81
10 182
15 347
20 537
21 625
24 670
Fill
5 20
10 45
15 73
20 110
25 165
30 244
35 341
40 463
45 625
48 650
fill
warp
% ELONGATION
TENSILE (psi)
0
5
10
15
20
25
30
35
40
0
100
200
300
400
500
600

FIGURE 34

6.5 PHASE IV Determination of carbon/oxygen ratios of polymer coating compounds on weatherometer aged and field aged tank samples:

Uniroyal Plastics Company, Inc. conducted an analysis of the weatherometer aged surfaces of samples exposed in Task I and the surfaces of samples of seven Uniroyal supplied tanks.

This surface analysis consisted of an X-ray photoelectron spectroscopic scan of the polymer surface to determine the carbon/oxygen ratio present. This measurement resulted in a quantitative measure of surface oxidation (degradation) which the coating compound has undergone. Uniroyal had these tests done at the University of Dayton Research Institute, 300 College Park, Dayton, Ohio 45469-0001. This data, as received from the University of Dayton, is presented in Appendix III of this report.

The data for the carbon/oxygen ratio tests run on weatherometer aged samples of four government supplied tanks is shown in Table XI.

TABLE XI

Carbon/Oxygen Ratio Data on Weatherometer Aged Samples

TANK DESCRIPTION		HOURS OF WEATHEROMETER EXPOSURE 0	500	1000	1500	2000
S/N W150 Uniroyal 50K Water Tank	C/O	6.8	3.1	4.9	3.3	9.9
S/N 84-25727 Goodyear 20K Water Tank	C/O	5.7	1.8	.87	1.35	1.35
S/N W155 Uniroyal 10K Fuel Tank	C/O	3.9	3.3	3.6	3.7	3.1
S/N 794 ILC Dover 10K Fuel Tank	C/O	2.5	2.8	1.9	2.1	1.9

The data from Table XI is presented in graph form in Figures 39 through 42, as shown on page 56.

FIGURE 39

S/N W150 50K Water Uniroyal

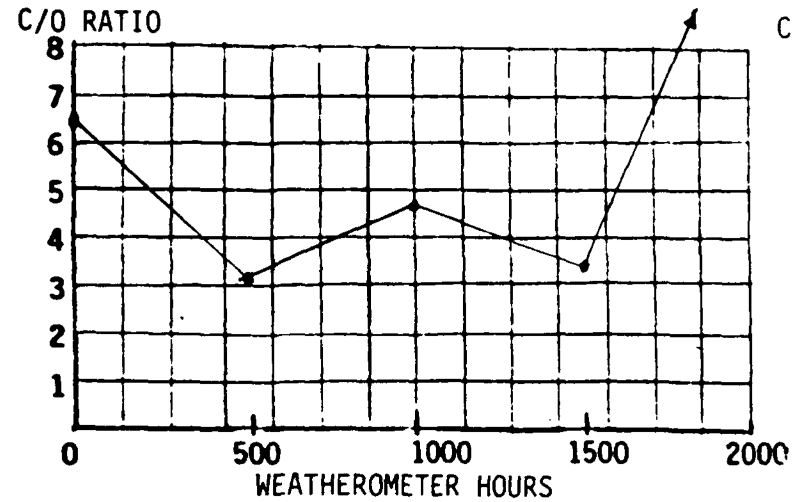


FIGURE 40

S/N 84-25727 20K Water Goodyear

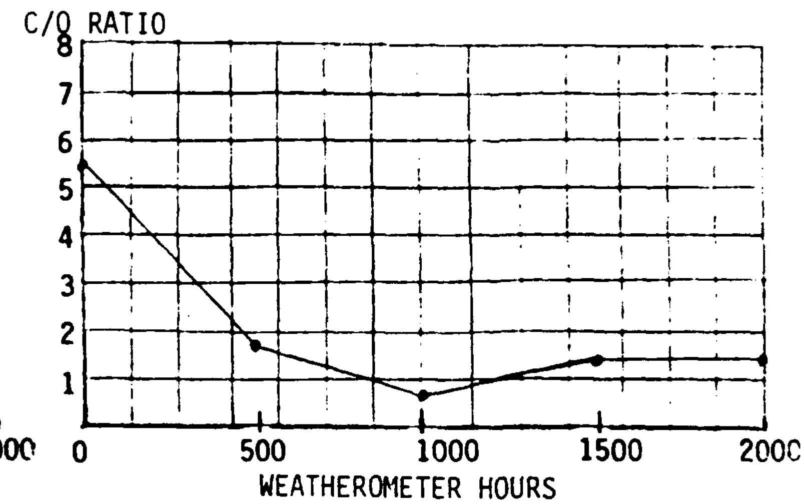


FIGURE 41

S/N W155 10K Fuel Uniroyal

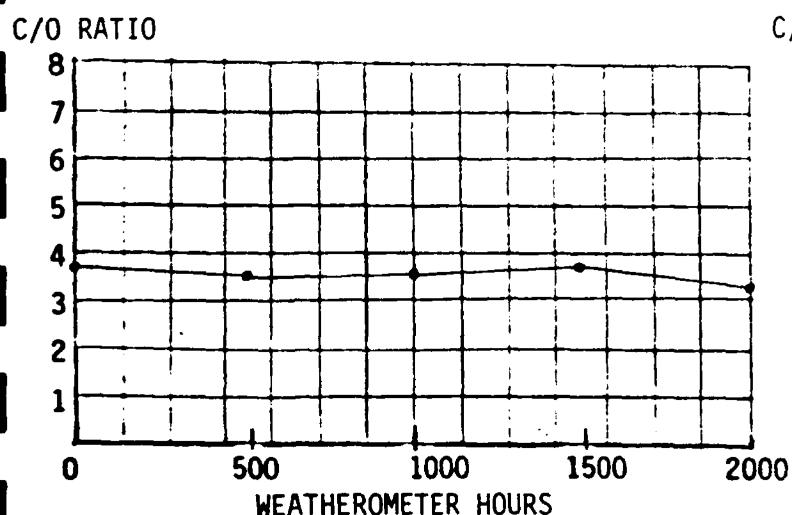
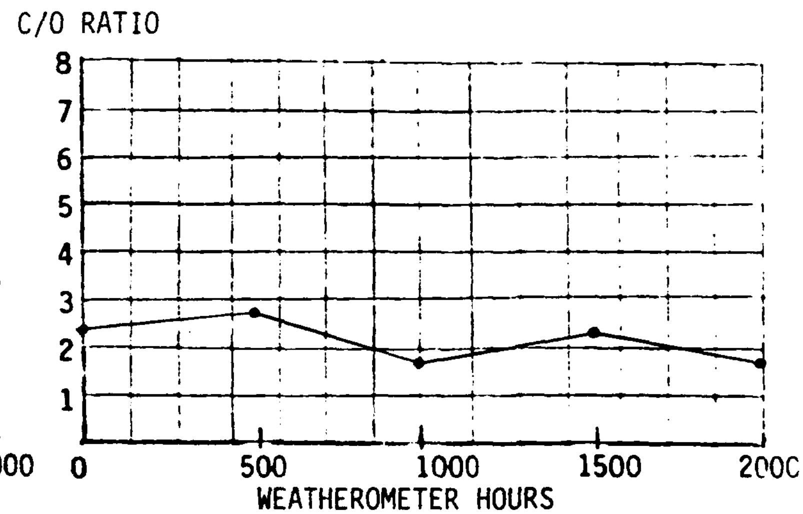


FIGURE 42

S/N 794 10K Fuel ILC Dover



Samples were removed from each of five Uniroyal fuel tanks and four Uniroyal water tanks of various ages. These samples were removed from the center of a fitting flange area. Samples consisted of a very small 3/8" x 3/8" section removed from the surface using a razor blade. Removal of a sample this small in a double or triple reinforced area will not affect serviceability of the tank. These samples were submitted to the University of Dayton for carbon/oxygen ratio testing. The results of this testing is shown in Table XII on page 57.

TABLE XII

Carbon/Oxygen Ratio Data on Uniroyal Tanks

TANK (FUEL)	MFG. DATE	AGE YEARS	C/O	TANK (WATER)	MFG. DATE	AGE YEARS	C/O
S/N W510 10K	5/81	7.2	2.9	S/N W6 10K	5/77	11.2	3.4
S/N W358 42K *	7/84	4.0	3.9	S/N W1 20K	10/81	7.3	5.0
S/N W9 10K	10/84	3.8	2.3	S/N W150 50K	3/83	4.8	6.8
S/N W1109 20K	2/85	3.4	2.4	S/N W2 10K	7/84	4.0	6.9
S/N W155 10K	11/85	2.6	3.9				

* This tank was in service for two years (diesel fuel).

A plot of data from Table XII is shown in Figures 43 and 44 below.

FIGURE 43

Uniroyal Tanks (Fuel)

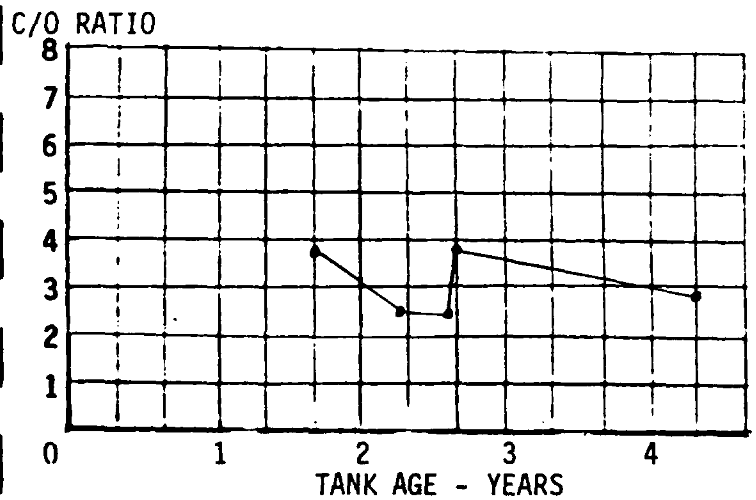
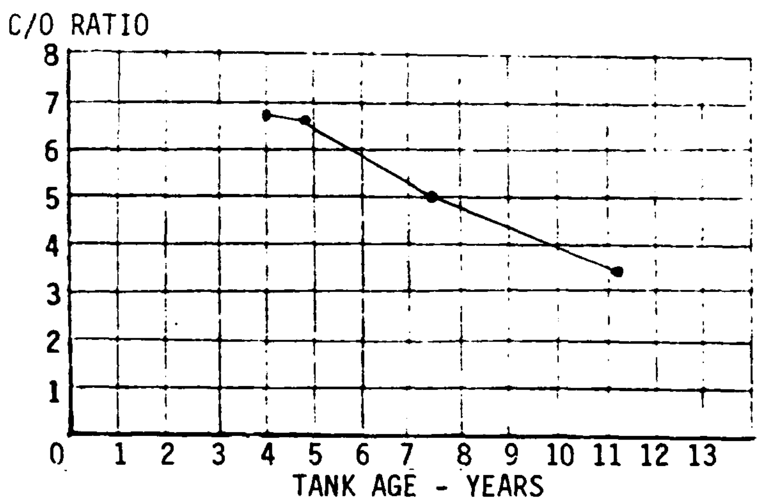


FIGURE 44

Uniroyal Tanks (Water)



A plot of tongue tear vs c/o at individual weatherometer agings was originally planned since the anticipated trends in the c/o ratio results and the tear values did not show a consistent drop in values with increasing weatherometer aging as anticipated. The graph of this data is meaningless. The data presented in this section will be further discussed in Phase V of this report.

6.6 PHASE V Date Correlation from PHASES I - IV

Uniroyal Plastics Company, Inc. proposed to correlate the data from PHASES I through IV to achieve a method to predict remaining tank service life via the following theories:

THEORY I (Proposed)

- The tank wall stress at maximum rated capacity can be calculated in terms of pounds per inch width for each given tank dimension/size.

- Tear strength degradation will eventually cause tank failure.

- The weatherometer data over a 2000 hour cycle will generate degradation curves for four government supplied tank constructions. Provided curves will demonstrate the aging impact on:

  tank fabric tensile (stress)
  tank fabric elongation (strain)
  tank fabric tear strength

- The weatherometer elongation vs time curve for the government supplied urethane tanks can be correlated to the strain measurement at maximum rated capactiy for the six Uniroyal tanks of known ages. Therefore, it is predicted that this correlation will permit the weatherometer hours to be translated into projected service years.

- The weatherometer data for the government supplied urethane tanks will be correlated to the tensile, elongation and tear properties of six Uniroyal tanks of known ages.

- If the weatherometer tear vs hours curve can be correlated to tear strength vs years of age, useful service can be predicted.

- The tear strength vs hours curve can be correlated to the elongation vs hours curve for the size tank construction. If the elongation capacity of a given tank can be determined through a non-destructive method, it can be directly correlated to the tear strength level at a comparable point on the weatherometer curve. From this information, the life of a given tank can be predicted with a reasonable degree of accuracy.

- Uniroyal proposed to provide a testing method for measuring the elongation capacity at an established stress level in order to determine, for a given tank, a projected use life. This test procedure will be totally feasible at depot or operational levels, requiring minimal man hours and recertification time.

THEORY II (Proposed)

- o As a tank's coating compound degrades (oxidizes), the reinforcement is also undergoing aging changes. Uniroyal proposed to correlate the carbon/oxygen ratio data (Phase III) obtained from the government supplied tanks and the carbon/oxygen ratio data (Phase III) on the Uniroyal supplied tanks to tank age and the weatherometer data. This correlation should result in predictability of tank service and, in the case of Uniroyal supplied tanks, a prediction of future service life.

- o Implementation of this evaluation method will require the extraction of a small quantity of the tank coating compound (less than .1 gm).

  NOTE: Compound sample can be taken from exterior chafing patch, fitting or handle flange.

  Said sample would be supplied to a testing facility capable of conducting the carbon/oxygen test. Results would then be correlated to an established degradation curve in order to predict future serviceability.

THEORY I (Results)

Two of the most important assumptions made in the proposed work plan for prediction of future tank service life were·

1. Tensile, elongation and tear properties would change significantly with increasing weatherometer aging up to 2000 hours.

2. The properties of the Uniroyal supplied (aged) tanks would demonstrate changes in physical properties with increasing age of the tanks tested.

The first assumption was incorrect in that the properties did not change significantly over the 2000 hour aging period. The recorded physical properties of the Uniroyal supplied tanks did not change significantly except in one area. This area is the tear strength of the Uniroyal supplied fuel tanks; this did drop significantly after three years of age.

Since these needed correlations, namely the weatherometer elongation vs time curve (Tables III and V) for the government supplied tanks correlated to the strain measurements at maximum rated capacity of the Uniroyal tanks of known ages (Figures 37 and 38), were not possible, it is not possible to translate the weatherometer hours into projected service years.

The weatherometer tear vs hours curves (Tables III and V) cannot be correlated to the tear strength vs years of age curve (Figures 35 and 36). This is because there is no significant change in the tear

vs weatherometer agings for both the fuel and water constructions and no significant changes in tear with age for the Uniroyal supplied water tanks, but rather significant changes in the tear properties of the Uniroyal supplied fuel tanks with age.

The weatherometer aged data does not provide useful information for predicting tank life expectancy fit for use information. The data from the Uniroyal tanks tested in this program and the non-destructive methods for determination of a tank's elongation at a given stress load may hold the key for fit for use and projected use life.

Figures 45 and 46 (pages 63 and 64) show plots of tear (W and F) vs tank age and elongation at 50# load (W and F) for the four Uniroyal supplied tanks having the same reinforcing tank fabric.

The trends shown in these graphs indicate that the tank tear drops with age as does the tank's elongation at a given load factor. This data is more pronounced for the fill direction than for the warp.

This correlation does not seem to be present in the data for the Uniroyal water tank construction (see Figures 36 and 38 in Section 6.4 of this report).

The data on the Uniroyal fuel tanks is very limited, but it does show that a method for determining tank serviceability and fit for use is possible using the following approach:

1. Determine a tank's elongation capacity in the fill direction at a given load by:

   A. The Uniroyal "clamp-on" test fixture.
   B. Air inflation and strain rosette measurements.
   C. Water inflation and strain rosette measurements.

2. Plot the elongation obtained against a chart similar to the ones shown in Figures 45 and 46 and read off the corresponding tear and age in years. If the tear value exceeds the anticipated wall stress for the tank in question, the tank is serviceable.

A projected service life can be predicted also from consulting the chart and determining the time remaining until the tear strength falls below the wall stress for the tank in question.

This method would be tank type specific and would eventually require standardization of fabric reinforcement. It would also require a data base much larger than the four tanks sampled under this program and would be required for each tank manufacturer.

The Uniroyal Plastics Company, Inc.'s "clamp-on" test fixture developed for this contract has proven its usefulness in determining tank elongations at a given stress load and also as a tool for

determining tank serviceability by spot checking seams of a suspect tank to determine if they will support anticipated filled stress loadings.

THEORY II (Results)

As was shown in Section 6.5, the anticipated correlation of data between carbon/oxygen ratios run on weatherometer aged specimens and weatherometer aged tear specimens was not possible.

Other unanticipated problems occurred which interfered with the anticipated degradation mechanisms described below.

The following descriptions are the mechanisms of degradation of materials utilized to produce military fuel and water storage tanks.

Nitrile and Chlorobutyl Materials - Degradation of these polymeric materials involves autocatalytic-free radical chain reaction. Free radicals are formed in rubber by heat, light, oxygen, etc. These free radicals then react with oxygen or rubber to produce more free radicals and degrade the polymer chain. This increase in oxygen content shows up in the c/o ratio determination. Rubber compounds are generally protected by antioxidants which react with the free radicals and prevent rapid polymer degradation until they themselves are depleted.

Polyurethane Materials - The predominant degradation mechanism for polyurethane polymers is hydrolysis. This process involves the combination of urethane with water to form an amine and carbamic acid which in turn react to form urea and carbon dioxide. This mechanism results in the polymer containing less oxygen with time as the polymer ages. This decrease in oxygen content shows up in the c/o ratio determination. Polyurethane compounds are generally protected by hydrolytic stabilizers which react with the water and prevent rapid polymer degradation until they themselves are depleted.

In theory, the c/o ratio should decrease as nitrile and chlorobutyl materials age and increase as polyurethane materials age.

During the weatherometer agings run on the chlorobutyl and nitrile materials there was an initial drop followed by a leveling off of the c/o ratios (except for the unexplained high peak c/o at 2000 hours for the S/N W150 chlorobutyl tank). The samples taken from the Uniroyal chlorobutyl tanks of various ages show a steady decline of the c/o ratios with time which is consistent with the degradation theory. Uniroyal feels that another influence may be affecting the weatherometer aged c/o data. This influence is the accumulation of scale on the surface of the samples from the water spray introduced on the samples in the weatherometer. This scale could mask the actual degraded surface and account for the lack of steady decline of the c/o ratio with increasing exposure.

During the weatherometer aging of the urethane materials an increase in c/o ratio was expected. Both the Uniroyal and ILC materials appear to have relatively the same c/o ratio throughout the test period. This could also be attributed to the scale formation on the sample surface. The samples taken from the field aged tanks show erratic behavior. One explanation is that since some of these tanks have seen filled service and have residual diesel fuel on their surfaces, this would change the base c/o ratio of the material and, hence interfere with the measurement of the actual degradation of the polyurethane. This should not however affect sampling tanks that have been stored, but not in service.

This non-destructive technique could be adapted for use in determining the serviceability of Uniroyal water tank constructions in the following manner:

1. Sample tank coating compound.
2. Submit sample for c/o ratio testing.
3. If c/o ratio is not below 3.4, the tank will demonstrate physical properties (i.e. tear) comparable to those shown in Figure 36.

The technique does not seem to have merit in the testing of fuel tanks due to the presence of residual fuel and fuel degradation products.

Further work done correlating artificially U.V. aged sample data to samples taken from field aged samples should be done in a fade-o-meter type machine which provides only U.V. exposure without the water spray.

FIGURE 45

WARP % STRAIN/TEAR/TANK AGE CORRELATION

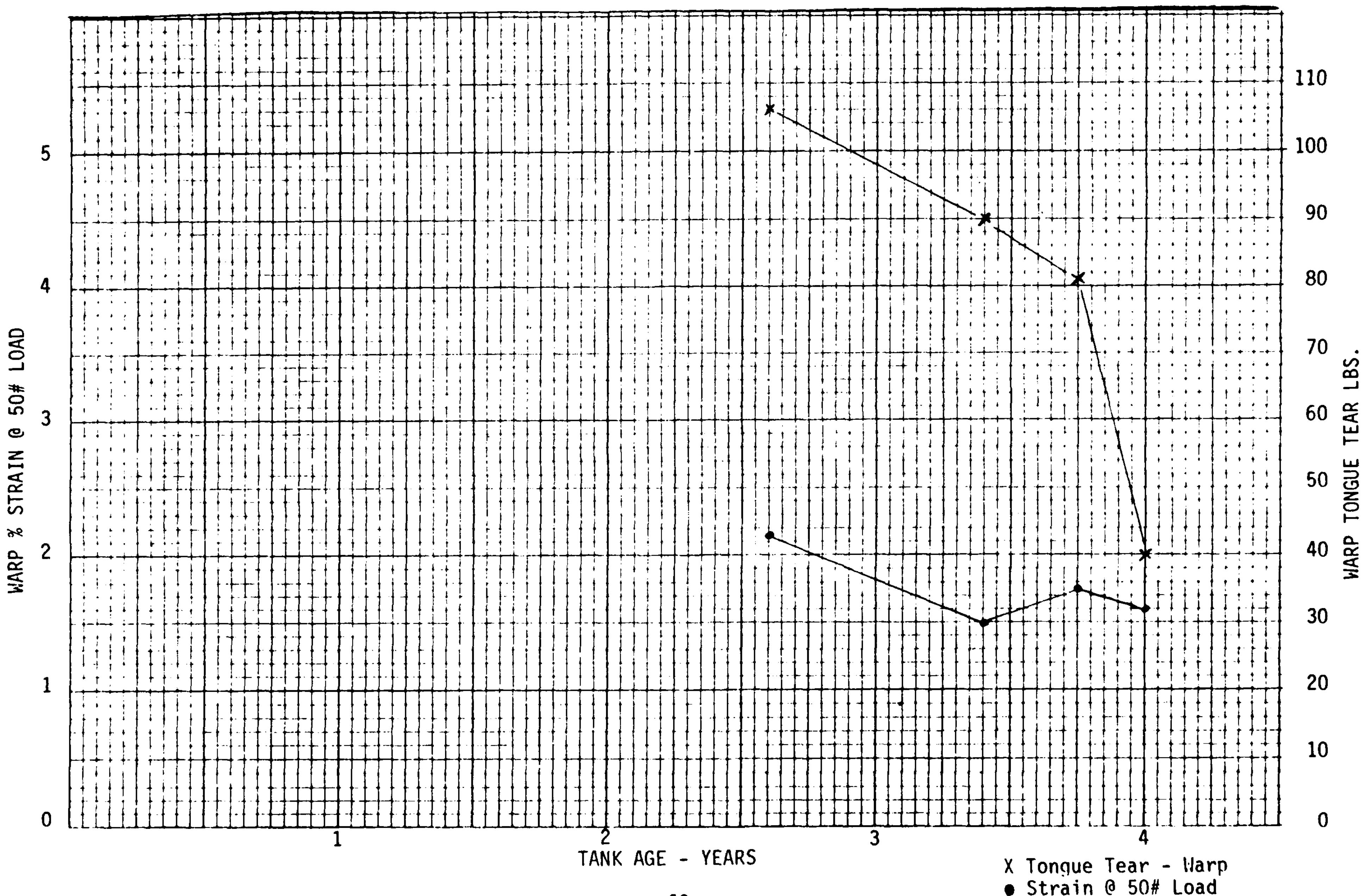
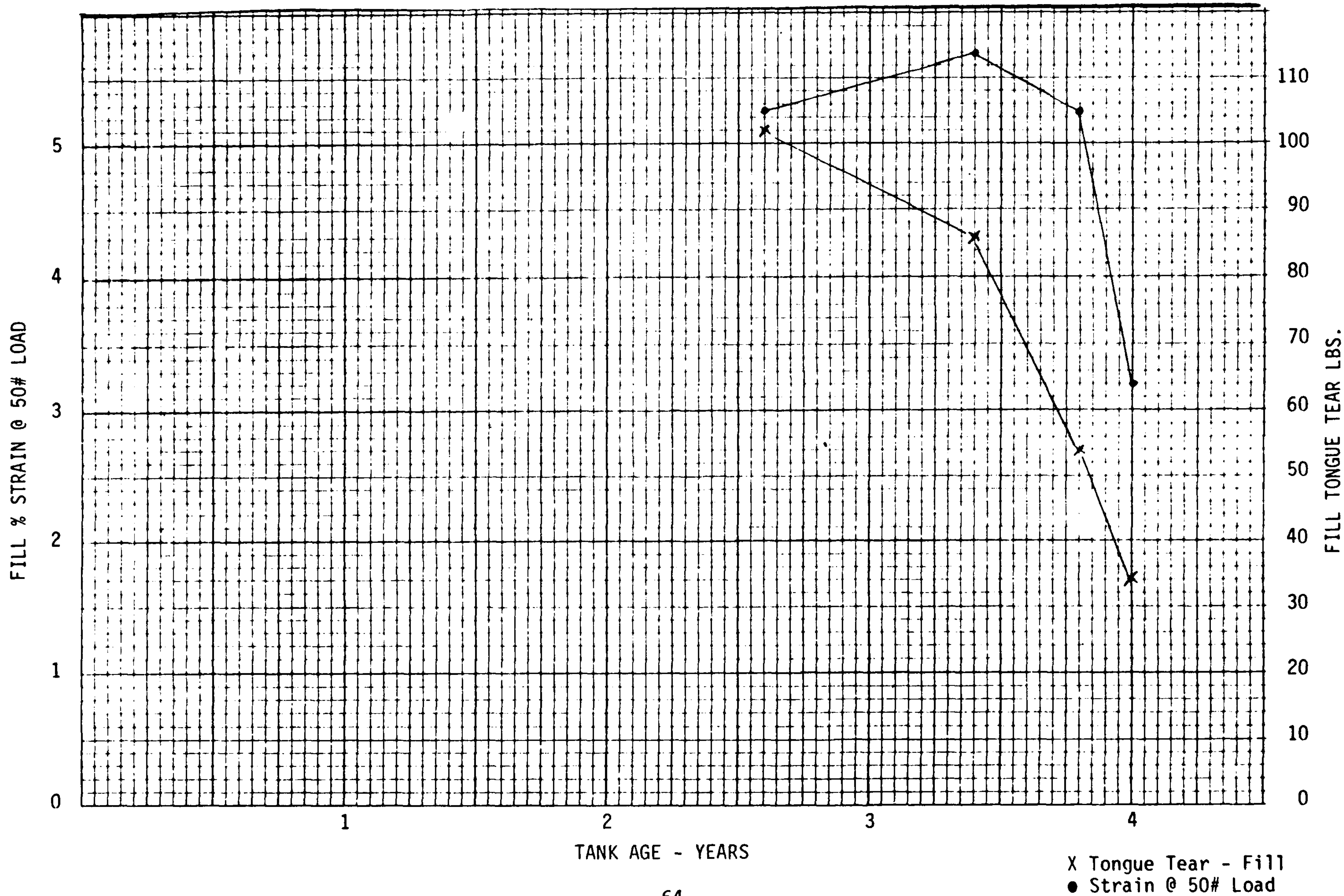


FIGURE 46

FILL % STRAIN/TEAR/TANK AGE CORRELATION



7.0 TASK IV ABRASION TEST RESULTS

7.1 Uniroyal Plastics Company, Inc., under the Technical proposal for this contract, had proposed the running of three different types of abrasion testing on each of the government supplied tanks. Part of the contract requirements was to determine an abrasion test method which would accurately correlate to the relative field performance of the different tank constructions. This information could only be obtained from government sources. This information was requested several times and was finally determined to be unavailable. At this point, Modification P002 was issued to the contract which stated that TASK IV was to be dropped and that Uniroyal Plastics Company, Inc. would publish all data obtained to date, with a list of equipment used. The tests run to this point and a description of the test equipment used are detailed in this section.

7.2 Abrasion - Rotary Platform Doublehead ASTM D-1175

Uniroyal Plastics Company, Inc. ran the abrasion test utilizing this equipment on two water tank constructions.

The proposed testing was to include the use of four abrasion wheel types (CS10, CS17, H18 and H22), 500 and 1000 gram loads with cycles to run 500, 1000, 1500 and cycles to wear to fabric reinforcement.

It was found that for the two water tank constructions tested that the CS10 and CS17 wheels were not abrasive enough to show any significant wear, even after 30,000+ cycles. These wheels were dropped from the test program in favor of the coarser H18 and H22 wheels. It was also determined that a standard load of 500 grams was not sufficient to obtain meaningful results in a reasonable length of time; the tests were then run at a 1000 gram load. The data obtained for the tests run, until the P002 Modification terminated testing, is shown below in Table XIII.

TABLE XIII

TANK DESCRIPTION	WHEEL	WT LOSS (GR) AT CYCLES SHOWN (1000 GR LOAD) 1000	1500	5000	TO FABRIC	CYCLES TO FAB
Uniroyal	H18	1.43	1.84	2.93	----	----
50K Water	H22	1.06	1.70	----	6.59	3555
S/N W150						
Goodyear	H18	4.23	6.41	----	----	----
20K Water	H22	4.10	4.68	----	9.75	3200
S/N 84-25727						

The above data indicates better performance by the Uniroyal construction than the Goodyear construction. It must be noted that this ranking does not necessarily relate to relative field performance, since the field data was unavailable for comparison.

7.3 Abrasion - Oscillatory Cylinder Method ASTM D-1175 (Wyzenbeek)

Uniroyal Plastics Company, Inc. conducted Wyzenbeek abrasion tests on two water tank constructions.

The proposed testing was to expose two samples of each tank construction to the abrasive effects of 40, 80 and 120 grit aluminum oxide abrasive cloth, wood and the tank material itself. The sample was to be under two pounds tension and two pounds load. The anticipated cycles to be run were 50, 100, 200, 250 and cycles to fabric +/- 25. Weight checks after each cycle time were to be measured and wear to fabric cycles noted.

During the early stages of the testing program, it became apparent that the two pound tension and two pound load settings resulted in excessively long testing required to expose the tank reinforcing fabric; 16,000 to 60,000 cycles. At this point, a series of tests were run increasing the tension to six pounds and the load to three and one-half pounds. The results of both sets of data are reported in Table XIV for each of the two water tank constructions tested.

TABLE XIV

TANK DESCRIPTION	ABRASIVE SURFACE	TENSION	LOAD	CYCLES TO FABRIC
Uniroyal	40 grit	2	2	60,000
50K Water	80 grit	2	2	20,000
S/N W150	40 grit	6	3 1/2	2,466
	80 grit	6	3 1/2	2,407
Goodyear	40 grit	2	2	23,158
20K Water	80 grit	2	2	16,200
S/N 84-25727	40 grit	6	3 1/2	3,182
	80 grit	6	3 1/2	4,278

It was at this point in the test program when the P002 Modification stopped this portion of the work effort.

As can be seen by the data, the Uniroyal construction performed far better than the Goodyear construction at two pounds tension and two pounds load; while at six pounds tension and three and one-half pounds load the Goodyear construction performed better. In order to determine which sets of conditions best duplicate field situations, it would be necessary for Uniroyal to know the relative field performance of these two constructions as it relates to abrasion resistance.

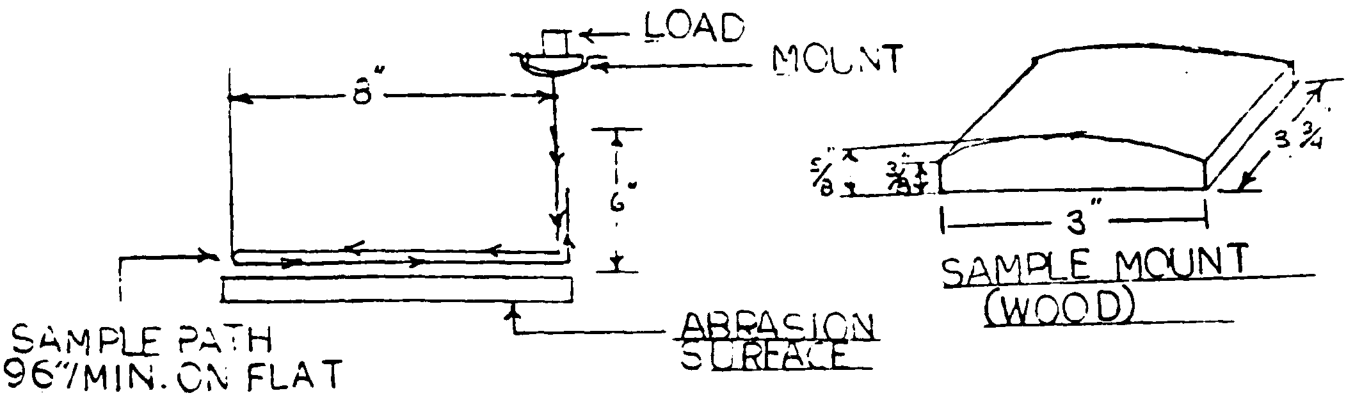
7.4 Uniroyal Dynamic Drag/Drop Abrasion Tester

Uniroyal Plastics Company, Inc. developed this piece of test equipment which combines a short drop under a given load with a reciprocal drag under load. This equipment has been utilized to test

the abrasion resistance of athletic equipment against various surface types. The action of this tester would simulate the conditions of a storage tank being dumped out of a crate onto an abrading surface and pulled along that surface. Figure 47 shows the path of travel of the test specimen. It was proposed that tarmac, crate wood and 40 grit aluminum oxide abrasive cloth be used for this test as the abrasion surface.

FIGURE 47

Uniroyal Drop/Drag Tester



Uniroyal Plastics Company, Inc. felt that this type of tester would yield the most meaningful results regarding the relative abrasion resistance of storage tank materials. The proposed test schedule (see Figure 48) was to be used as a guide only. Sufficient samples were to be run to fine-tune the procedure. One set of samples was also to be run mounting the samples in such a manner that the edge (corner of a double fold) would be subjected to the abrasion surfaces.

FIGURE 48

Uniroyal Drop/Drag Tester Test Plan

Abrading Surface	Cycles* to Fabric		
	5 lbs	1.0 lbs	2.0 lbs
Crate wood Tarmac 40 grit abrasive			

* Cycle = 1-6" drop, 1-8" push, 1-8" pull

Work had progressed to the point where the tester had been run on a very limited basis on Uniroyal tank materials. Modifications were in progress to set the weight requirements to best suit the materials being tested, when this portion of the contract was terminated by Modification P002.

It is still felt by Uniroyal Plastics Company, Inc. that this type of test would be useful in determining the relative abrasion resistance in a relatively short test cycle and would simulate field type situations.

7.5 Comments on types of abrasion tests, as they relate to field conditions:

It is Uniroyal Plastics Company's opinion, from our experience, that the Rotary Platform Doublehead (Taber) abrasion method would best duplicate:

1. Abrasion encountered when tanks are dragged on a sand surface.

2. Abrasion encountered when a tank is being filled with a large hose and high gpm pump. Under this condition, buffetting occurs on the tank bottom causing movement on the sand base, resulting in tank abrasion.

The Oscillatory Cylinder Tester (Wyzenbeek) will best duplicate abrasion conditions experienced when a tank is crated and being transported; abrasion against crate, itself, or if uncrated, against dirt or sand in the transport vehicle.

The Drop/Drag Tester will best duplicate conditions experienced during tank handling, both for the initial installation and removal from service.

8.0 TASK VI ANALYSIS OF PACKAGING, HANDLING AND REPACKAGING

8.1 The following is an analysis of packaging, handling and repackaging techniques. The individual topics to be addressed are:

A. Crate design
B. Tank positioning and protection inside the crate
C. Tank deployment techniques and procedures
D. Procedures utilized to remove the tank from service and repackaging

8.2 Crate Design:

Although the tank specifications have been revised to require a heavy-duty, reusable lag-bolted wooden crate, the following recommendations should be considered in order to optimize protection for the storage tank and components:

1. Specified inside dimensions should be established for each tank size. (The size would be adequate to contain all manufacturer's tanks. The size would also be such as to allow for field use folding and repacking.)

2. The crate should be of such design that only the lid is removed, with all of the contents remaining inside. The crate could contain a false bottom floor in which all hardware, including hoses could be stored in the crate bottom; a sub-floor placed over the tank in the crate and the ground cloth stored on top for easy access.

   The tank would be better protected, especially on repack, after field duty, where all the preservation items may be lost.

3. In order to keep the crate lid together with the crate, draw pull latches could be permanently attached to the crate (see Figure 49).

   FIGURE 49

   Draw Pull Latch

8.3 Tank Positioning and Protection Inside the Crate:

1. All tanks and ground cloths should have folding indicators permanently marked so all folding is done the same way, especially on repack.

2. All tanks and ground cloths, regardless of construction materials, should be placed into an individually sealed, water/vapor-proof bag, providing a sealed atmosphere. This need only be done at initial packaging/packing at the manufacturer's facility. Bagging the tank and ground cloth will increase the tank shelf-life of both. Lining of the crate can then be eliminated.

3. A sling should be designed for each size tank so the tank can easily be lifted from and placed back into the crate without totally disassembling the crate.

   A sling can be economically constructed from present Military Standard webbing and buckles.

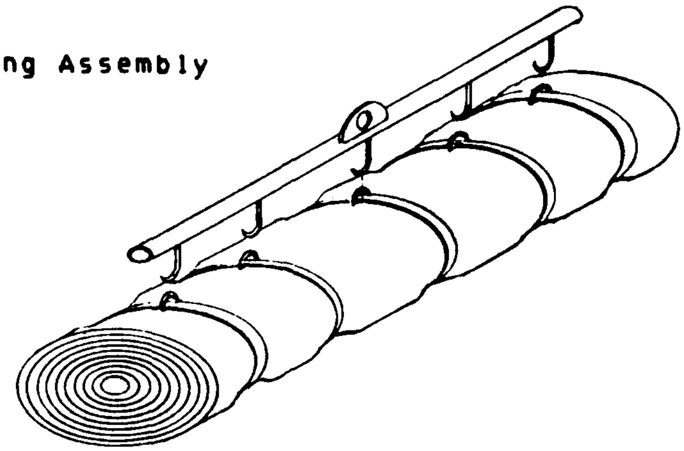
   The sling can also be used to transport and position the tank at the deployment spot.

4. Another alternative to a sling would be a lifting bar.

   Each deployment sight would have a lifting bar capable of lifting up to 50,000 gallon tanks. The tanks would be bound in their rolled, folded form using webbed belting, buckles and delta rings. The lifting bar hooks would match the delta rings and the tank then lifted from the crate (see Figure 50).

FIGURE 50

Lifting Bar/Sling Assembly



8.4 Tank and Ground Cloth Deployment Techniques and Procedures:

Specific deployment techniques and procedures are of utmost importance. These techniques and procedures should include, but not be limited to:

1. Instructions on removing the lid from the crate.

   A special document instructing the removal of the lid should be placed in a vapor-proof envelope and attached to the outside of the lid between the supporting cleats. This document should also define where to find the Operations and Maintenance Manual.

2. The Operations and Maintenance Manual should define the removal of the ground cloth from the crate and the method of location and unfolding.

3. The manual should instruct the use of the sling to remove the tank from the crate and place it into a deployment position, correctly onto the ground cloth, so they are properly located to each other.

4. The Operations and Maintenance Manual should also include a chapter on salvaging the preservation material and handling of the crate when not in use.

   The preservation material should be stored inside the crate and the crate lid held in place with draw pull latches (see Paragraph A.3).

8.5 Procedure Utilized to Remove Tank from Service and Repacking:

The emptying procedures found in Technical Manual TM5-5430-219-13 & P are accurate. Greater detail in repacking is required, especially the removal of residual fuel:

1. The removal of residual fuel.

Based on our field observations during military training operations, there is great difficulty in removing approximately 30 to 50 gallons of residual fuel. Attempts were made to remove this fuel through the drain assembly, which is located 6 feet away from the end of the tank. One of the most dramatic methods was to cut the tank at one corner and roll the tank towards that corner. UNIROYAL feels that it is feasible to add a small fitting at the bottom corner of the tank to which the drain hose could be attached when emptying the tank. The tank could then be rolled towards this end/corner and the residual fuel extracted through the hose into a receptacle.

Another option of removing the residual fuel is to add an additional small I.D. suction hose, which can be inserted through the fill/discharge assembly and then pump the residual fuel out.

2. Sub-assemblies.

Sub-assemblies should be removed from the tank; cushioning placed around all hardware, if still available, and stored under the sub-floor where the hardware could not damage the tank.

3. Refolding of the tank.

Since each tank is the same size, folding indicators should be permanently marked on each tank at fabrication. These indicators would allow the tank to be field folded similarly to the folding performed by the manufacturer.

4. Sling.

The sling should be positioned on the tank to store it in the crate.

9.0 CONCLUSIONS

9.1 The results of the 2000 hour weatherometer aging show good performance of all tank constructions tested. All physical properties of all tanks tested were well within a safety factor of two for supporting tank stress loadings when filled to their rated capacity, regardless of the % retention of those properties. It appears that a 2000 hour weatherometer exposure does not duplicate conditions in the field which could cause catastrophic tank failures; a much longer exposure period is required.

9.2 The seam peel and shear test results show excellent performance of both tanks when subjected to each of the test fluids for 14, 28 and 42 days at 160°F. In fact, both tank constructions meet or exceed the original test requirements after 42 day immersions in each test fluid.

The test results for fitting shear also show good results except for the curved section of the access door cut from the ILC tank and tested for originals, 14 day Fuel B and 14 day MIL-F-46162B fuel + EGME. These values fell below MIL-T-52983C specification requirements. However, the averages of the straight and curved sections passed and the 28 and 42 day values for the curved sections were well above the specification minimums.

9.3 The use of the Uniroyal designed "clamp-on" test fixture for determining tank wall elongations at given stress loadings proved very feasible. This non-destructive method enables an investigator to determine a tank's serviceability and also provides data concerning the stress/strain characteristics of the tank body material.

9.4 Methods were developed to determine a tank's elongation characteristics during air testing and water fill.

9.5 Physical property vs tank age graphs were developed for Uniroyal water and fuel tanks which, when developed on a larger data base, can be used coupled with non-destructive test methods and used to predict serviceability and service life.

9.6 Techniques were developed for determining carbon/oxygen ratios for field aged tanks which, in the case of Uniroyal water tanks, can be used to predict tank serviceability.

9.7 Several test methods were investigated to relate abrasion test methods to tank serviceability. This effort was terminated in the middle of the investigation because the government was unable to provide relative field performance data on tanks manufactured by different suppliers.

9.8 Since a large percentage of storage tank field failures are caused by mishandling of the unit during unpacking, deployment and repacking, particular attention needs to be given to the recommendations made in the Task III, Phase VI section on Analysis of Packaging/Handling and Repackaging Techniques.

10.0 RECOMMENDATIONS

10.1 In view of the recent changes in MIL-T-52983 revision D and proposed revision E regarding tensile retention after weatherometer aging, serious consideration needs to be given to the validity of this test as a method for predicting tank longevity. If any physical property should be measured after weatherometer exposure it should be a tear property rather than a tensile property. The criteria should be an absolute minimum value rather than a % retention figure, which is meaningless when it is related to tank serviceability.

10.2 Adopt the use of the "clamp-on" tension tester as a method for determining tank serviceability and expand the data base on tanks manufactured by different suppliers so that measurements made could be used to predict remaining tank use life.

10.3 The government agencies using fuel and water storage tanks need to implement a program of tracking tank field performance so that a data base can be established enabling manufacturers to zero in on problem areas which could positively impact storage and service life. This data base should include the relative abrasion resistance of tank types in service.

APPENDIX I

UNIROYAL COMMENTS ON TANK FAILURE MODES

APPENDIX I

UNIROYAL COMMENTS ON TANK FAILURE MODES

Uniroyal Plastics Company's involvement in commercial markets has enabled us, through our customer service efforts, to gain a vast amount of information on tank field performance.

Uniroyal Plastics Company's experience in field performance of water and fuel tanks has led to these conclusions regarding tank performance and service life:

- Mechanical Damage: By far the most prevalent mode of tank unserviceability is related to damage incurred during tank deployment or removal from service. This damage consists of: (most frequent first)

  1. Holes due to abrasion caused during deployment

  2. Punctures from foreign objects incurred during deployment or unpacking.

  3. Tank being cut open during removal from service to remove residual fuel or water.

  4. Cuts, holes, abrasions due to removal from service and storage outside in unprotected areas. (Wooden packing crates are not reuseable.)

- Degradation of Materials: Tanks which are handled properly or are deployed initially and left at one location may eventually fail in service through the following modes:

  1. Degradation of polymer coating followed by degradation of the fabric reinforcement, leading to tensile and or tear failure of the reinforcement fabric. The tensile failure occurs when the hoop stress from the filled tank exceeds the remaining reinforcement strength. Tear failure occurs when the hoop stress of the filled tank exceeds the remaining tear strength of the degraded fabric. This type of failure occurs at points of stress concentration such as seam edges, fitting flanges, mechanical repair clamps or plugs. These types of failures tend to be catastrophic in nature resulting in a tank tearing open from end to end. This type of problem can usually be spotted and the tank removed from service prior to catastrophic failure.

  2. Degradation of seam adhesive or seam interface (heat sealed): This condition is caused by attack of water, fuel and fuel decomposition products on the seam adhesive. It is

characterized by a lifting up of the seam edge with progressive intrusion into the seam. Signs of impending failure is characterized by seeping at seam edges. This type of degradation can be spotted and a tank exhibiting these problems can be removed from service prior to catastrophic failure.

3. Tank overfilling: Tanks are inadvertently overfilled and failure occurs from tensile failure of the reinforcement fabric at points of stress concentration. The area of greatest stress concentration is located at the oval access/fill fittings. Traditionally, failure occurs at this point followed by tearing of the coated fabric until the hoop stress level is lower than the tear strength of the fabric.

4. Isolated manufacturing defects not detected with contractor controls or specification testing: These defects (primarily associated with bonded seam areas) can cause premature tank failure.

APPENDIX II

USE OF "CLAMP-ON" STRESS/STRAIN TEST FIXTURE

- o Procedure
- o Figures 1 through 13
- o Drawings I and II

APPENDIX II

PROCEDURE

USE OF STRESS/STRAIN TEST FIXTURE

Step 1 Mark area to be tested perpendicular or parallel to seam using carpenter square.

Step 2 Bulge-up material in marked area. (Figure 2)

Step 3 Pinch fold in tank material and wrap partially around knurled rod "A".* (Figure 2)

Step 4 Place mainframe "B" over tank material and knurled rod. (Figure 3)

Step 5 Slip lower jaw "C" onto guide pins and insert bolt "D" and tighten assembly. (Figure 4) Figure 5 illustrates fixed end assembly.

Step 6 Slip loose jaw "E" with adjustment screw onto guide rods "F". (Figure 6) (Adjustment screw to project approximately 1" through frame.)

Step 7 Pinch fold in tank material and wrap partially around knurled rod "G". Fit folded material and knurled rod into upper jaw "E". (NOTE: Adjustment screw should be resting on ball bearing on gauge "L".) (Figure 7)

Step 8 Slip lower jaw "H" onto guide pins and insert bolt "J" and tighten assembly. (Figure 7)

Step 9 Remove slack between jaws by placing thumb on end of guide rod "F" and using fingers to pull back on sliding jaw assembly. (Figure 8)

Step 10 Turn adjustment screw "K" to rest on ball bearing on gauge "L". (Figure 9) (Allow slight preload 2 to 5 lbs.)

Step 11 Turn adjustment screw clockwise to initially stress material to approximately 150 lbs for one minute. (Figure 10)

Step 12 Back off adjustment screw "K" so that gauge stops, then set gauge to zero. Measure and record distance between jaws with Vernier caliper. (Figure 11)

Step 13 Again turn adjustment screw "K" to predetermined load from chart; keep readjusting until gauge settles.

Step 14 Measure and record distance between jaws with Vernier caliper. (Figure 13)

Step 15 Subtract initial reading from second reading - divide result by initial reading and multiply by 100 to get percentage strain.

* See Drawing I and Drawing II for test fixture detail.

NOTE: Additional items required:

1. 1/2" socket
2. Vernier calipers
3. Flat blade screwdriver
4. Carpenter square

FIGURE 1

FIGURE 2

FIGURE 3

FIGURE 4

FIGURE 5

FIGURE 6

FIGURE 7

FIGURE 8

FIGURE 9

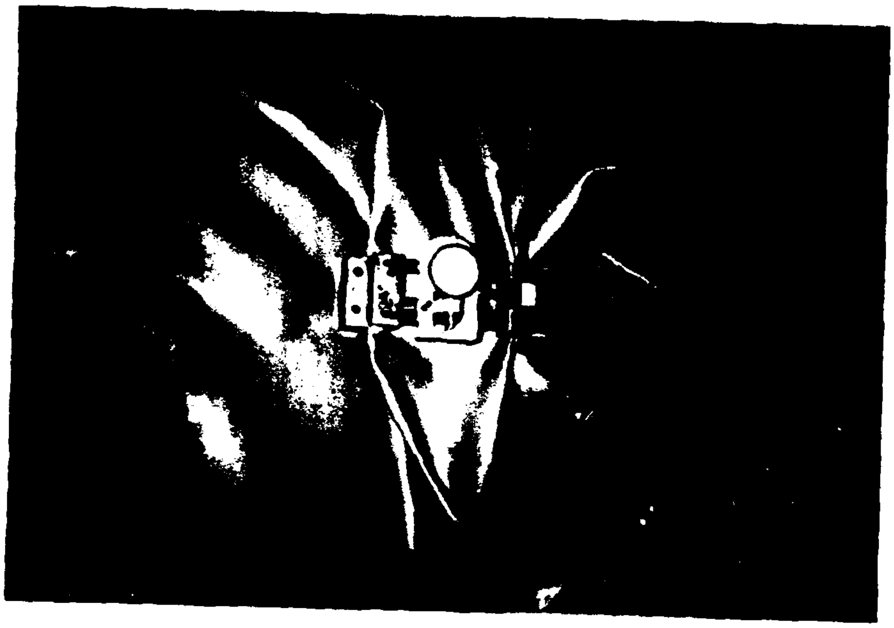


FIGURE 10

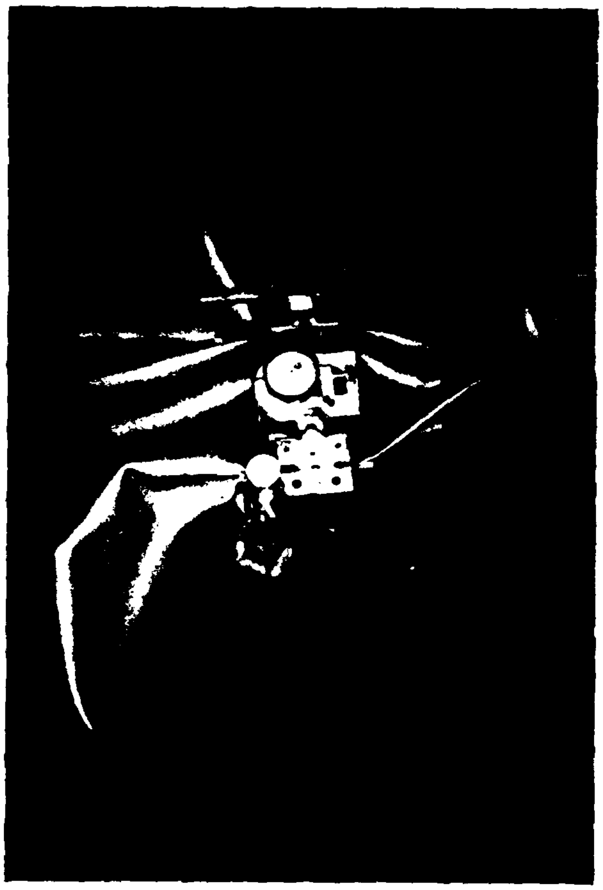


FIGURE 11

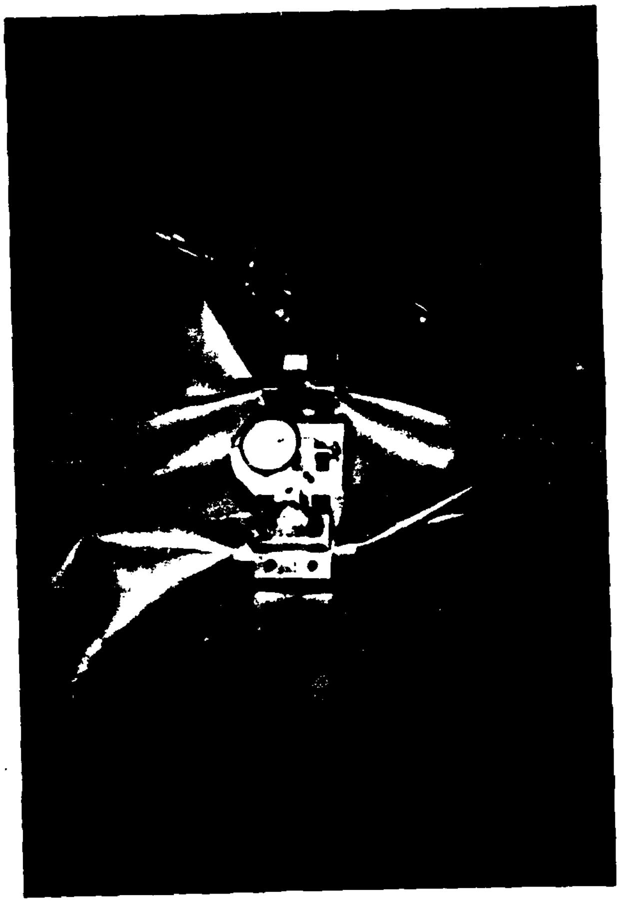


FIGURE 12

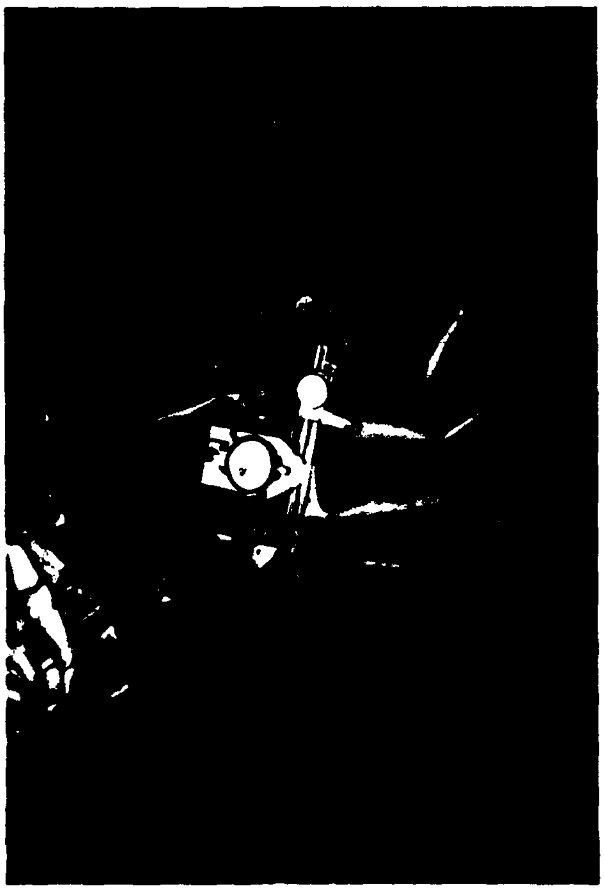
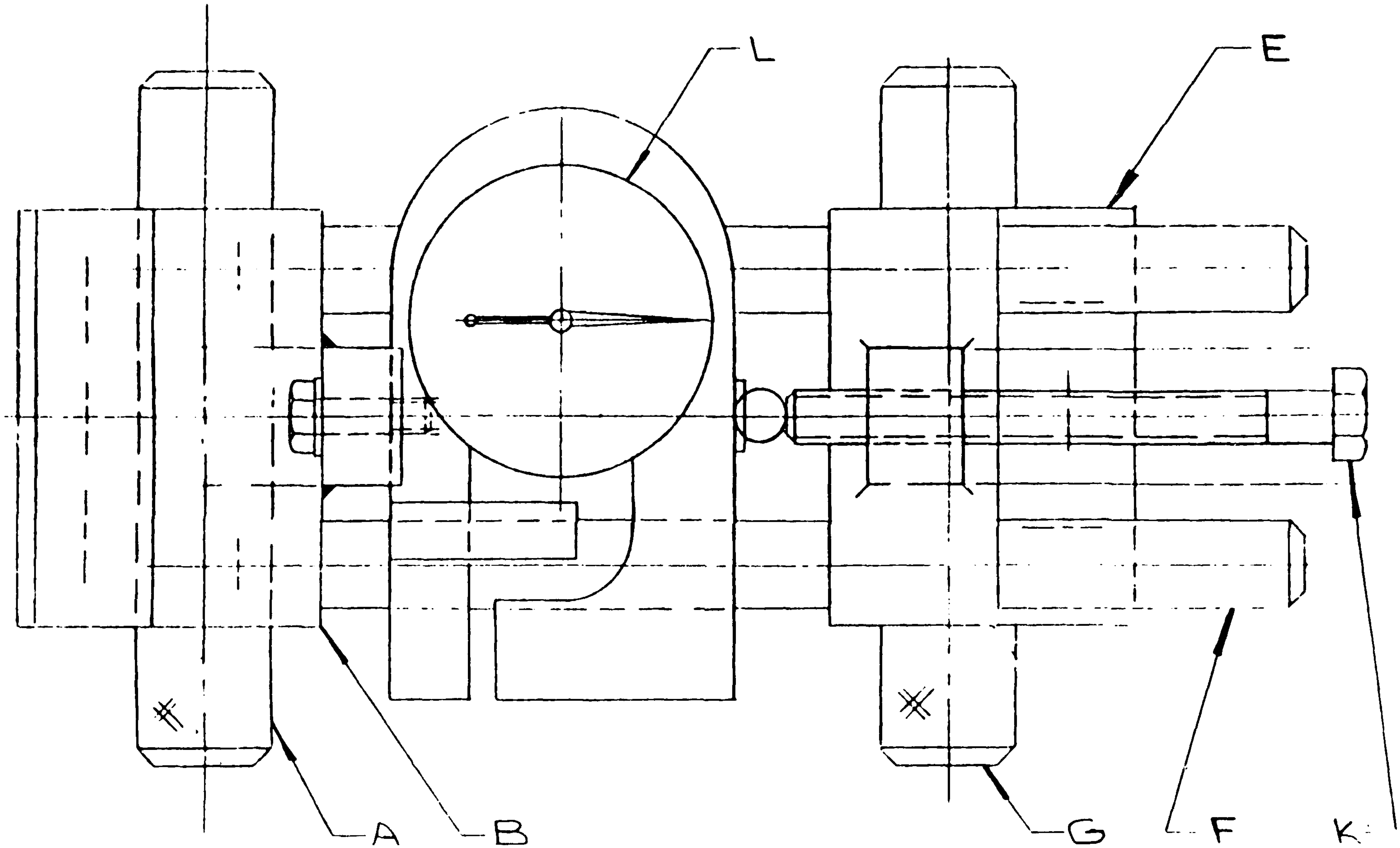
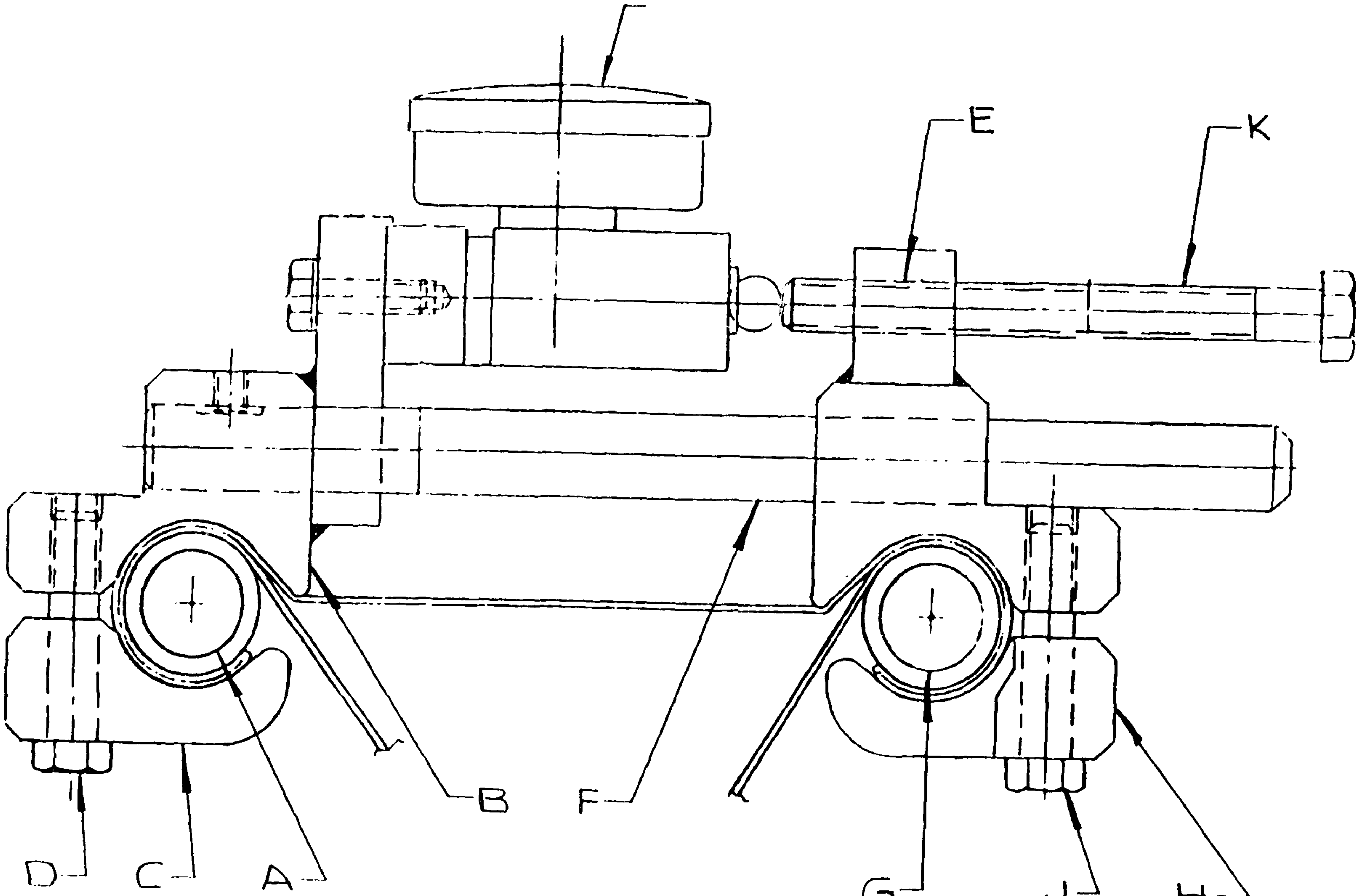


FIGURE 13



DRAWING I
STRESS STRAIN TEST
FIXTURE

7/8/88 DVP



DRAWING II

STRESS STRAIN TEST

FIXTURE

7/8/88 DVP

APPENDIX III

UNIVERSITY OF DAYTON

C/O RATIO TEST DATA

The University of Dayton

26 July 1989

Mr. G. E. Colley
Uniroyal Plastics Company
312 North Hill Street
P.O. Box 2000
Mishawaka, IN 46544

Dear Mr. Colley:

I have used XPS to analyze the ten elastomer samples that we received from you last week. The following table gives the measured carbon-to-oxygen atom % ratios for the surfaces that were away from the adhesive tape in each envelope.

Sample		% Carbon/% Oxygen
UNI-S/N W 150	2000 hrs	9.9
ILC-S/N 794	500 hrs	2.8
"	1000 hrs	1.9
"	1500 hrs	2.1
"	2000 hrs	1.9
UNI-S/N W 155	500 hrs	3.3
"	1000 hrs	3.6
"	1500 hrs	3.7
"	2000 hrs	3.1
GDY-S/N 84-25727	2000 hrs	1.35

The survey scans for these samples show that in all cases, elements other than carbon and oxygen are detected. On each of the ILC-S/N 794 samples, for example, small amounts of iron, silicon, calcium, and nitrogen are detected on the surface.

Please call me if you have any questions about these results.

Sincerely,

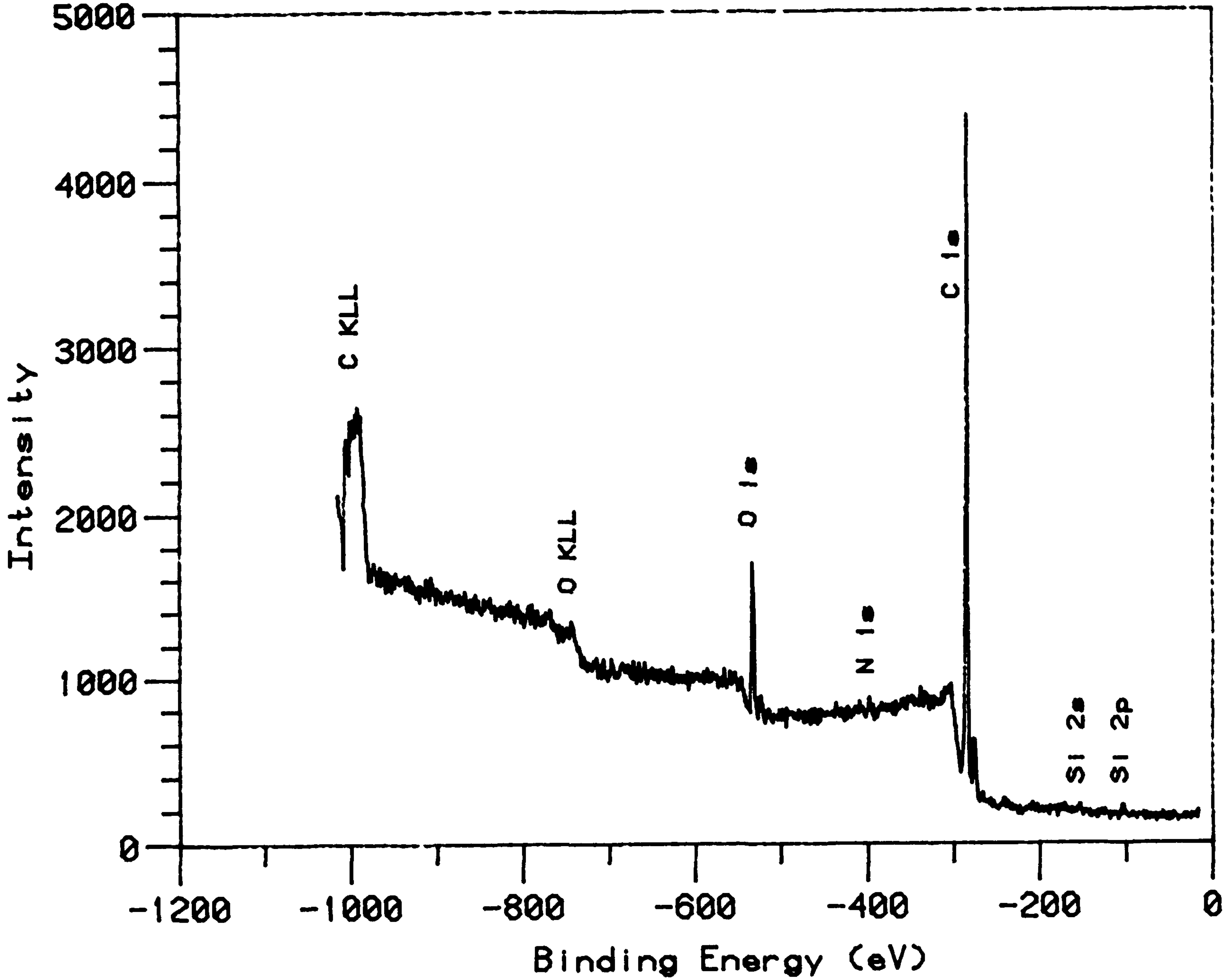
Tom Wittberg

Tom Wittberg

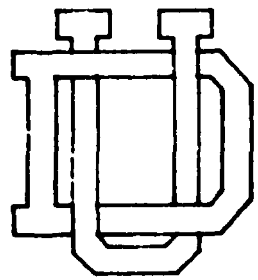
TW:prc

Enclosures

UNIROYAL UNI - S/N W15 2000 Hrs.
XPS Survey Scan



PARAMETERS
Iter= 15
Dwell=0.1s
Inc=1.000eV

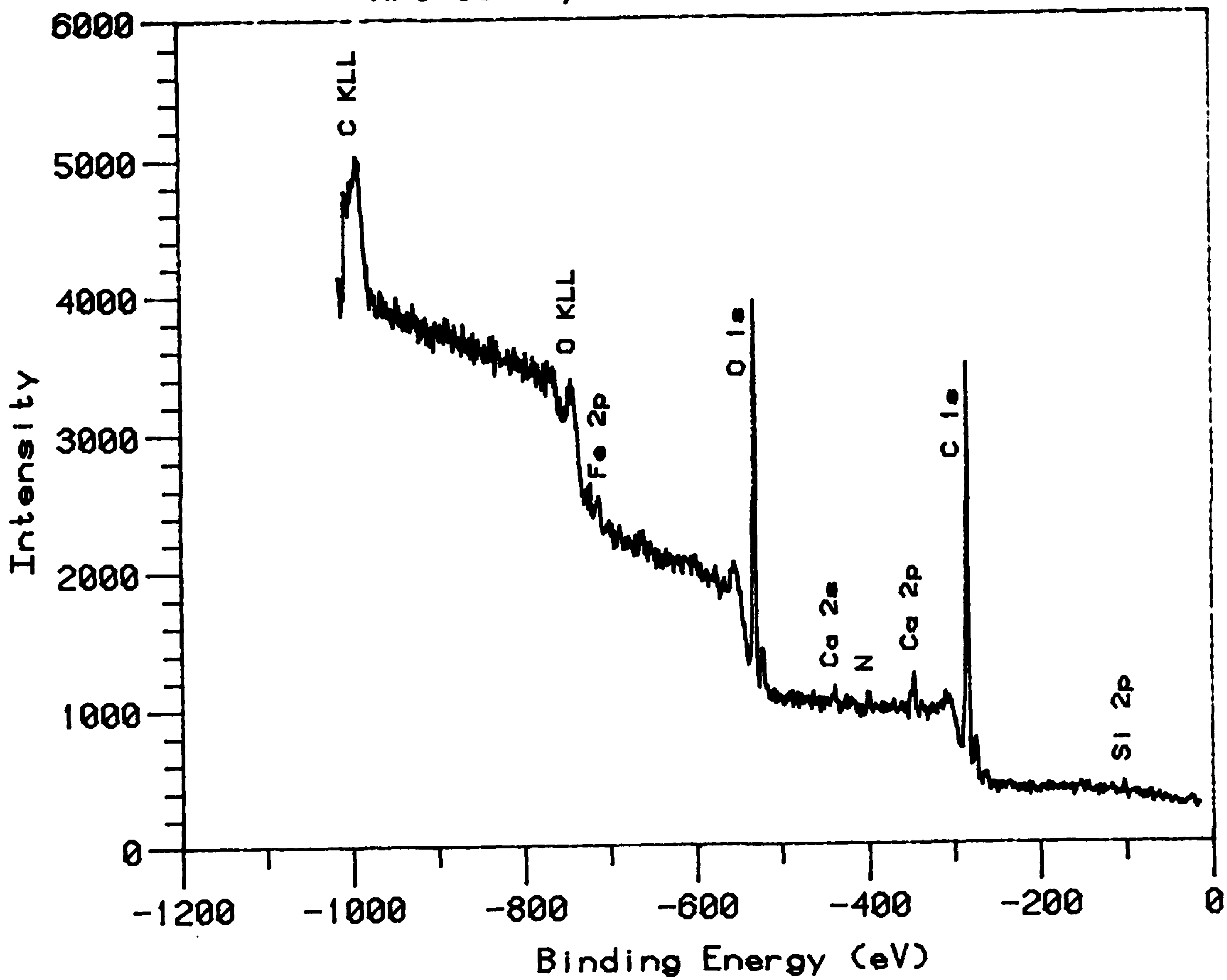


Operator: TW
Version: 02B

File: 072489.e02

UNIROYAL ILC - S/N 794 500 Hrs.

XPS Survey Scan



PARAMETERS

Iter= 15

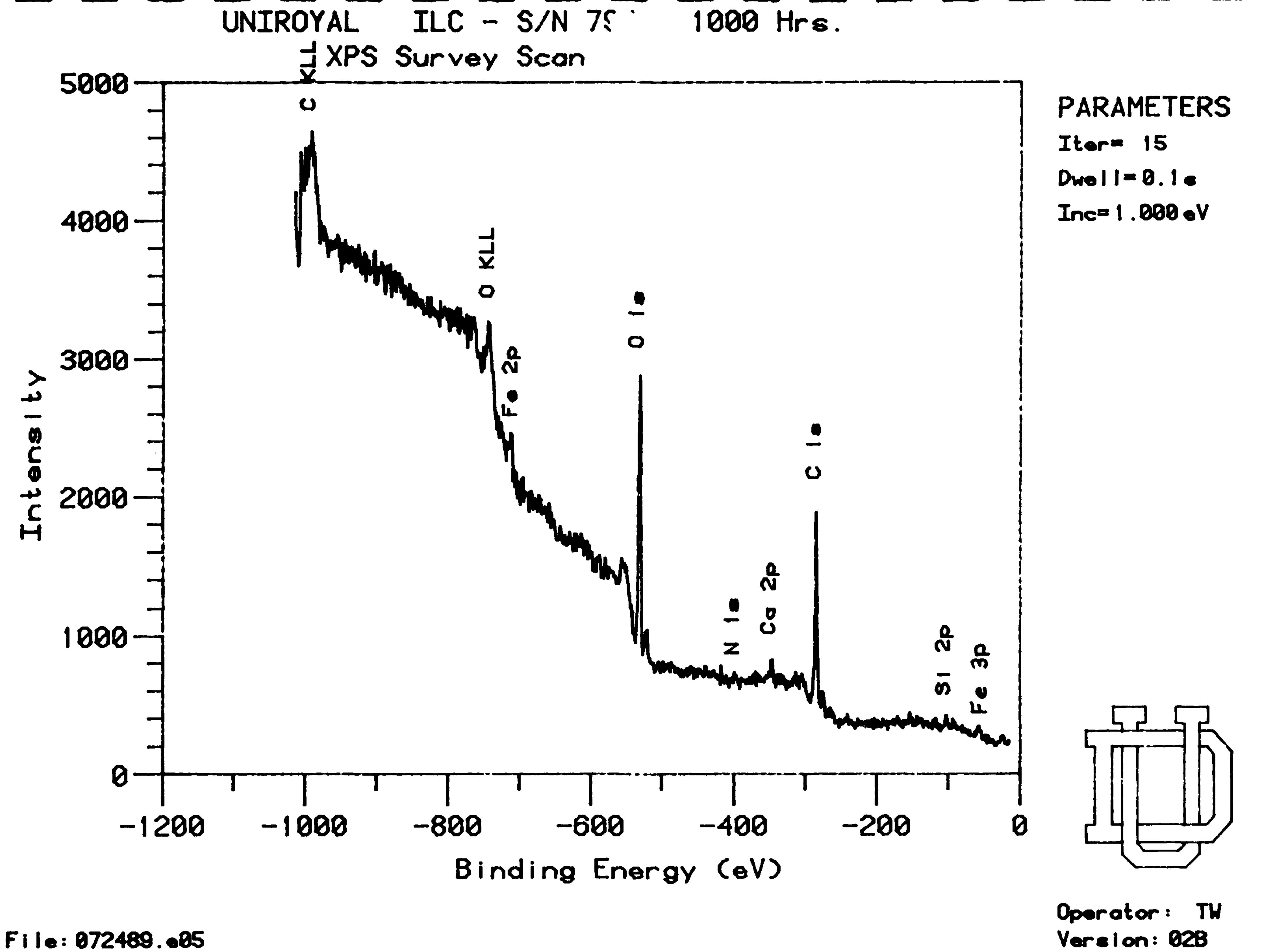
Dwell=0.1s

Inc=1.000eV

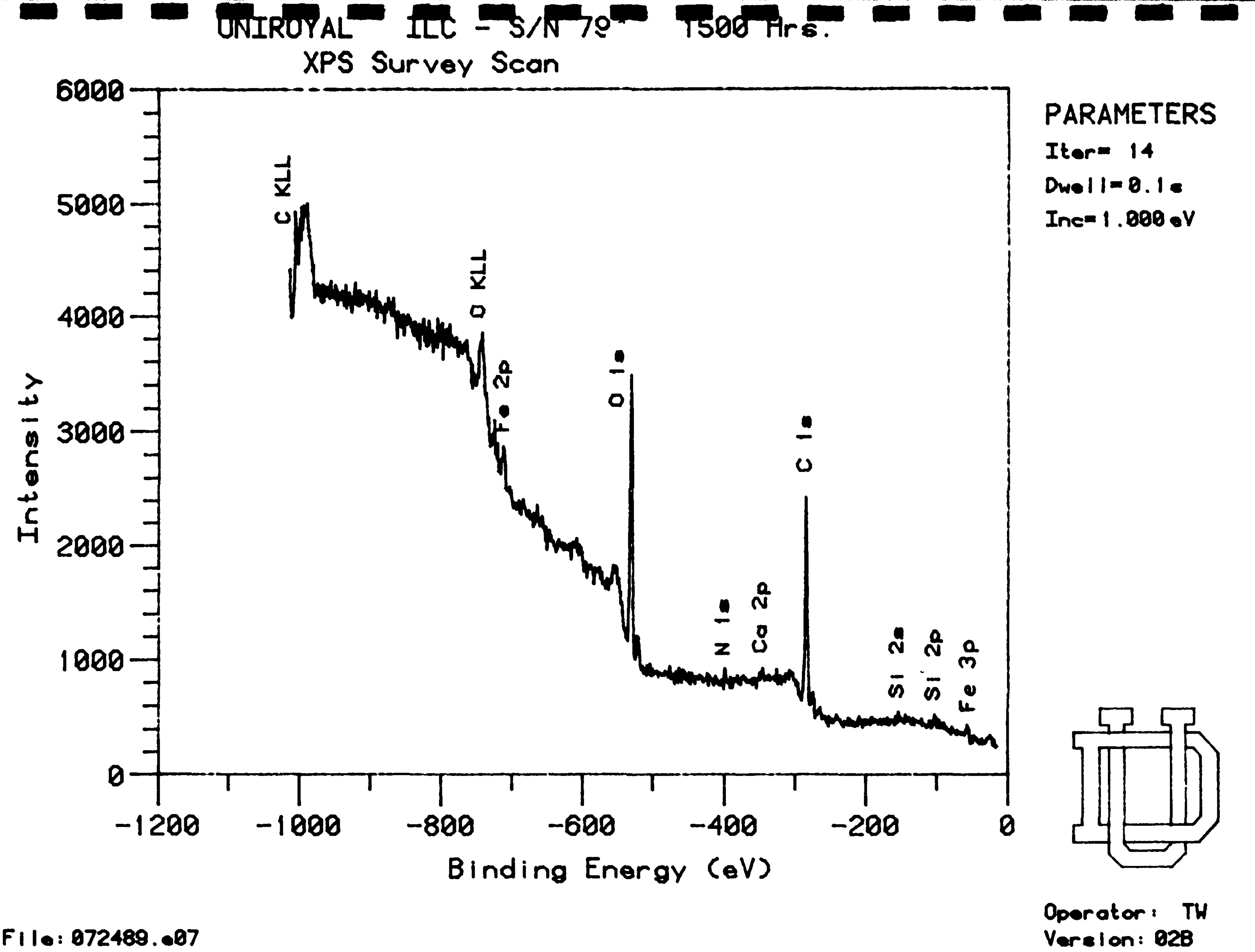
Operator: TW

Version: 02B

File: 072489.e03

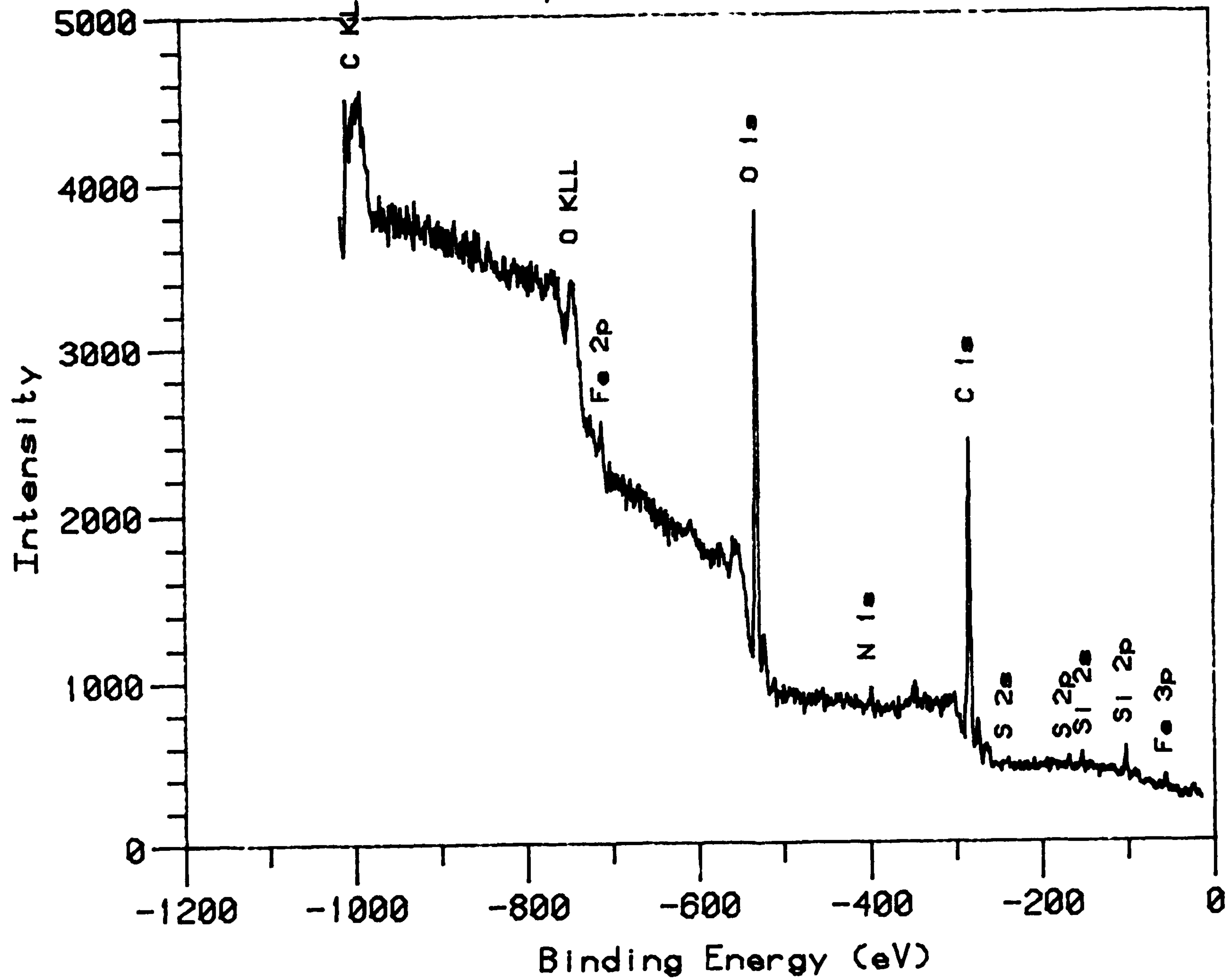


UNIROYAL ILC - S/N 7S 1000 Hrs.
XPS Survey Scan
C KLL
O KLL
Fe 2p
O 1s
N 1s
Ca 2p
C 1s
Si 2p
Fe 3p
Intensity
5000
4000
3000
2000
1000
0
-1200
-1000
-800
-600
-400
-200
0
Binding Energy (eV)
PARAMETERS
Iter= 15
Dwell=0.1s
Inc=1.000eV
Operator: TW
Version: 02B
File: 072489.e05


UNIROYAL ILC - S/N 79 1500 Hrs.
XPS Survey Scan
Intensity
6000
5000
4000
3000
2000
1000
0
C KLL
O KLL
Fe 2p
O 1s
N 1s
Ca 2p
C 1s
Si 2s
Si 2p
Fe 3p
-1200
-1000
-800
-600
-400
-200
0
Binding Energy (eV)
PARAMETERS
Iter= 14
Dwell=0.1s
Inc=1.000eV
Operator: TW
Version: 02B
File: 072489.e07

UNIROYAL ILC - S/N 79 2000 hrs.

XPS Survey Scan



PARAMETERS

Iter= 12

Dwell=0.1s

Inc=1.000eV

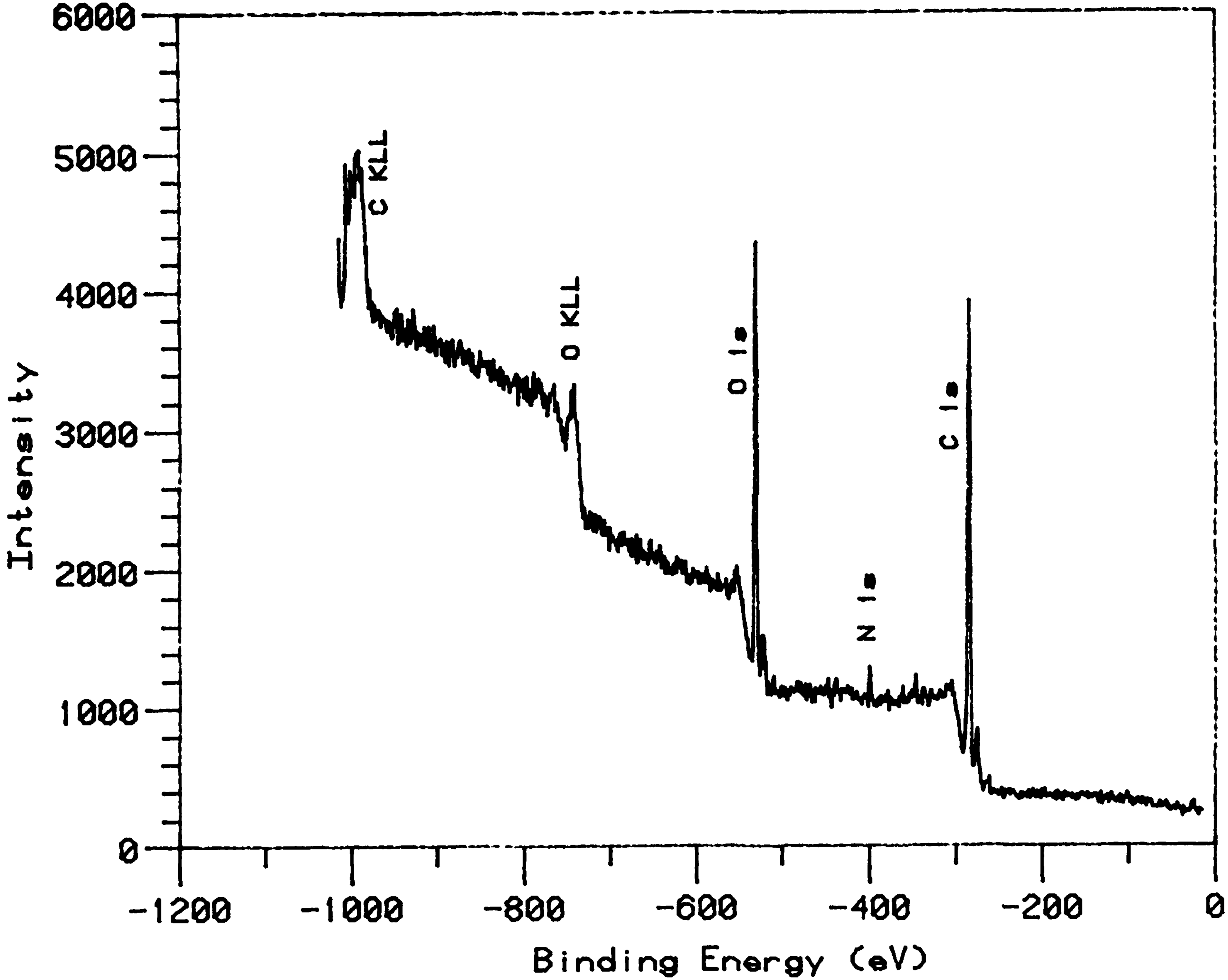
Operator: TW

Version: 02B

File: 072489.e09

Uniroyal UNI - S/N W1 5 500 Hrs.

XPS Survey Scan



PARAMETERS

Iter= 18

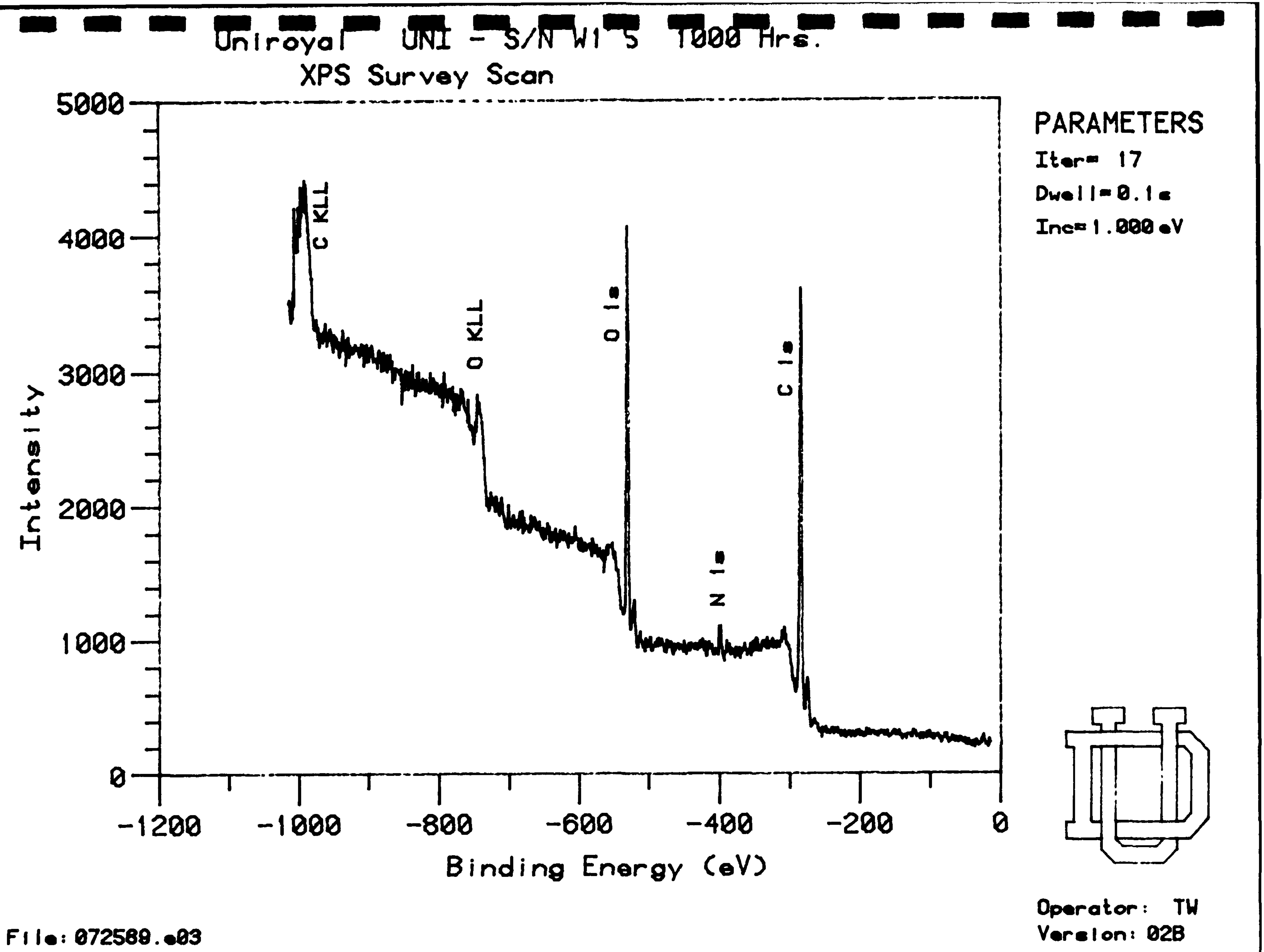
Dwell=0.1s

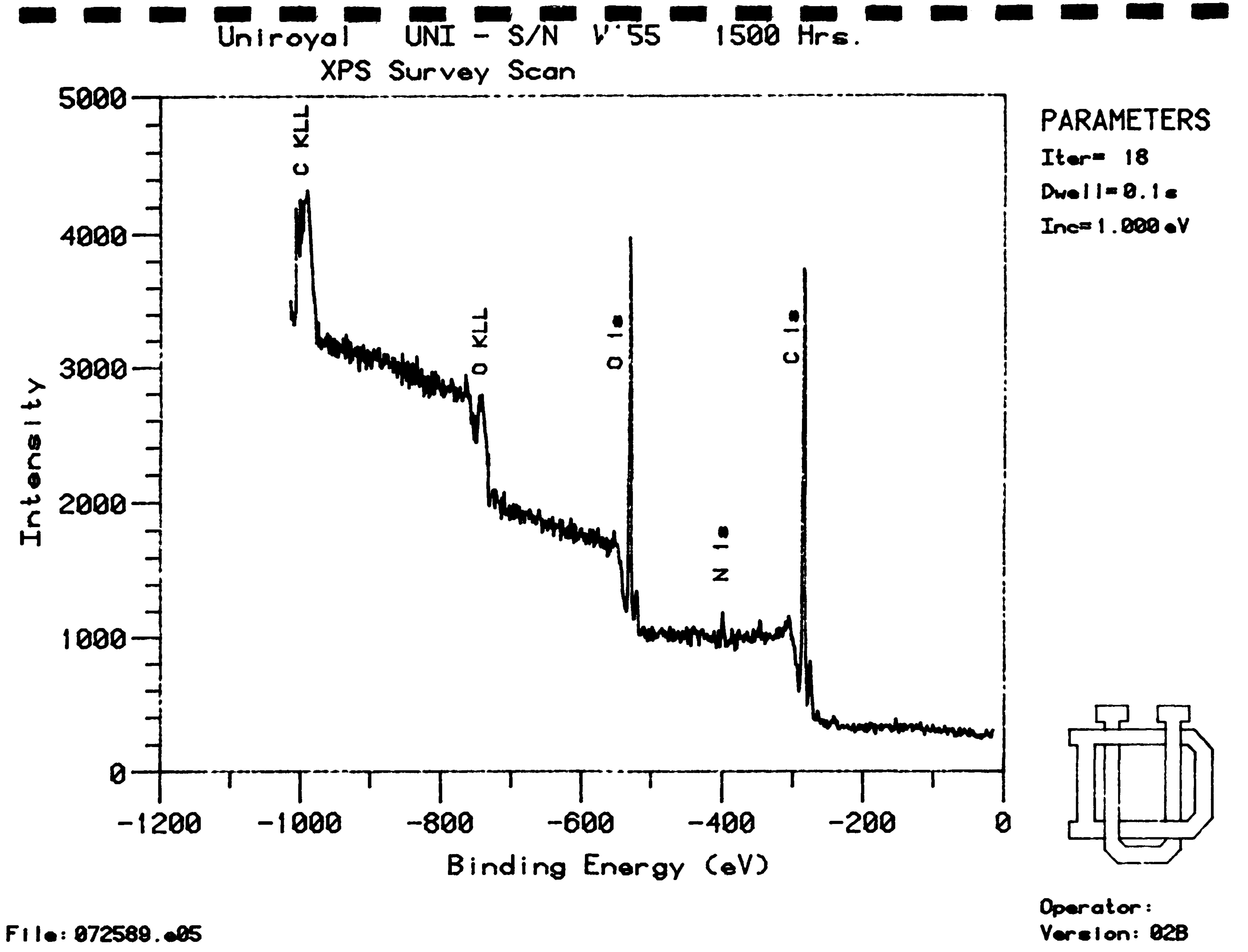
Inc=1.000eV

Operator: TW

Version: 02B

File: 072589.E01

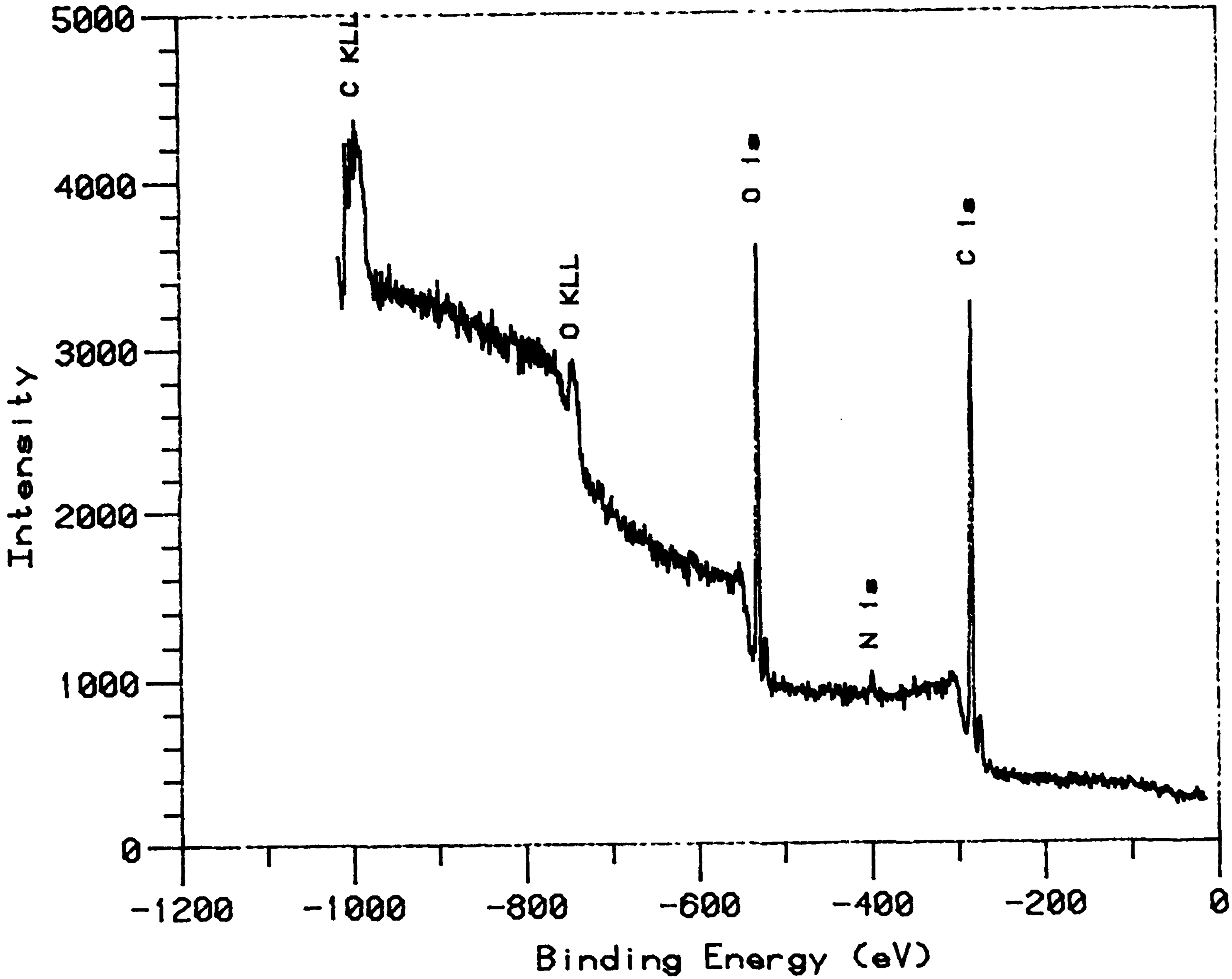

Uniroyal UNI - S/N W1 S 1000 Hrs.
XPS Survey Scan
5000
4000
3000
2000
1000
0
Intensity
C KLL
O KLL
O 1s
N 1s
C 1s
-1200
-1000
-800
-600
-400
-200
0
Binding Energy (eV)
PARAMETERS
Iter= 17
Dwell=0.1s
Inc=1.000 eV
Operator: TW
Version: 02B
File: 072589.e03



Uniroyal UNI - S/N V'55 1500 Hrs.
XPS Survey Scan
5000
4000
3000
2000
1000
0
Intensity
C KLL
O KLL
O 1s
N 1s
C 1s
-1200
-1000
-800
-600
-400
-200
0
Binding Energy (eV)
PARAMETERS
Iter= 18
Dwell=0.1s
Inc=1.000eV
Operator:
Version: 02B
File: 072589.e05

Uniroyal UNI - S/N W15 2000 Hrs.

XPS Survey Scan



PARAMETERS

Iter= 17

Dwell=0.1s

Inc=1.000eV

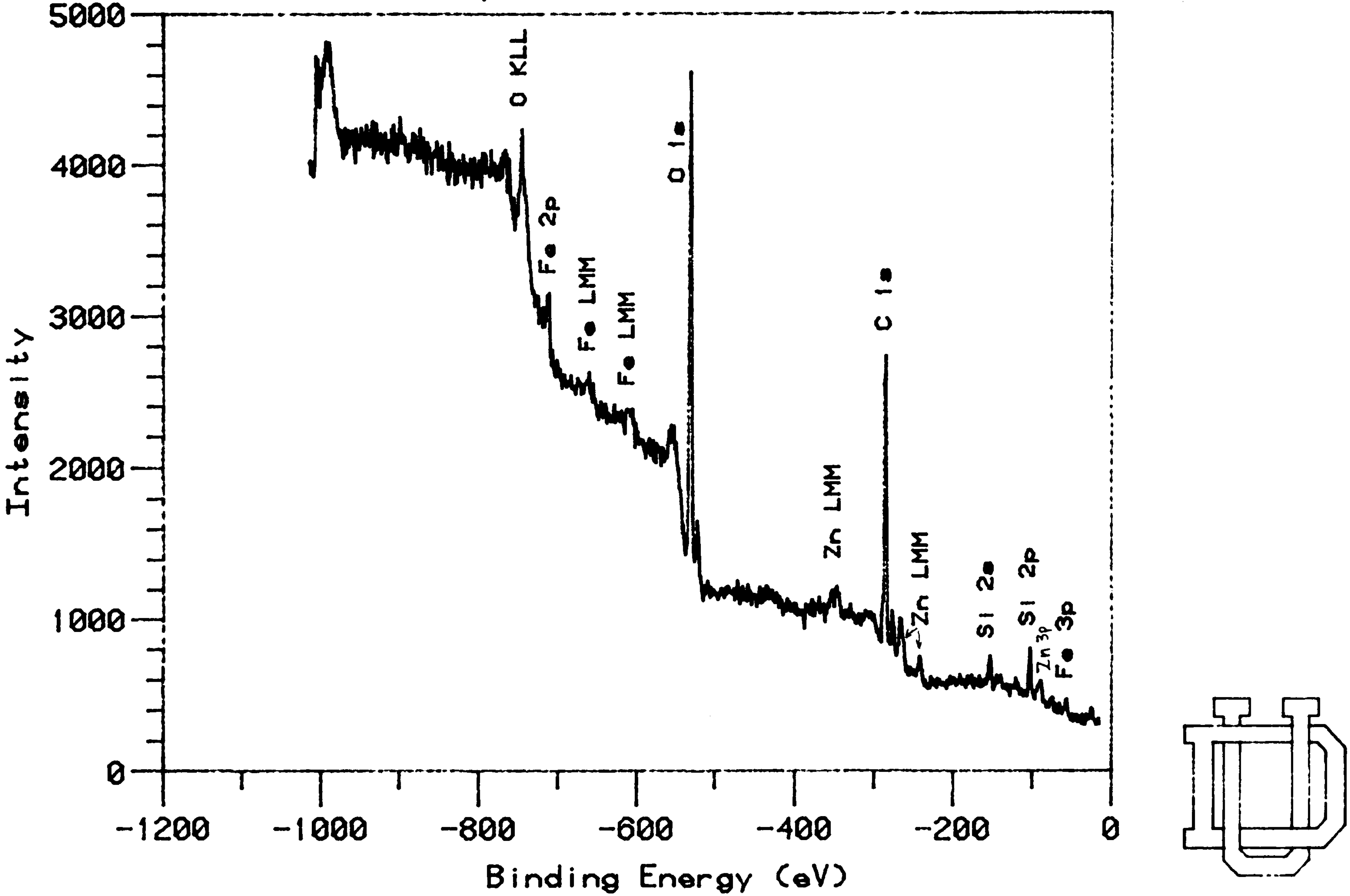
Operator:

Version: 02B

File: 072589.e07

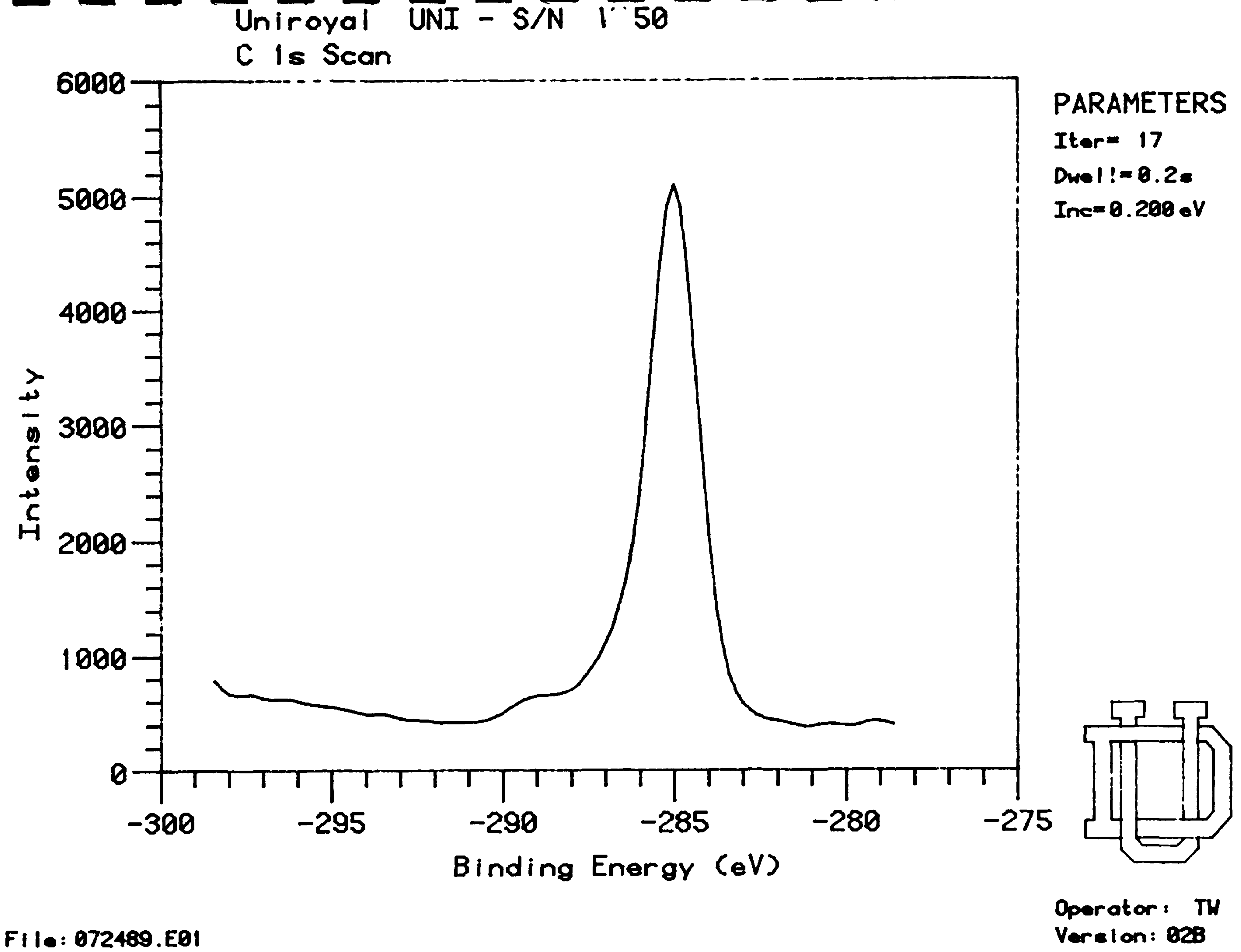
Uniroyal GDY - S/N 84-2727 2000 Hrs.

XPS Survey Scan

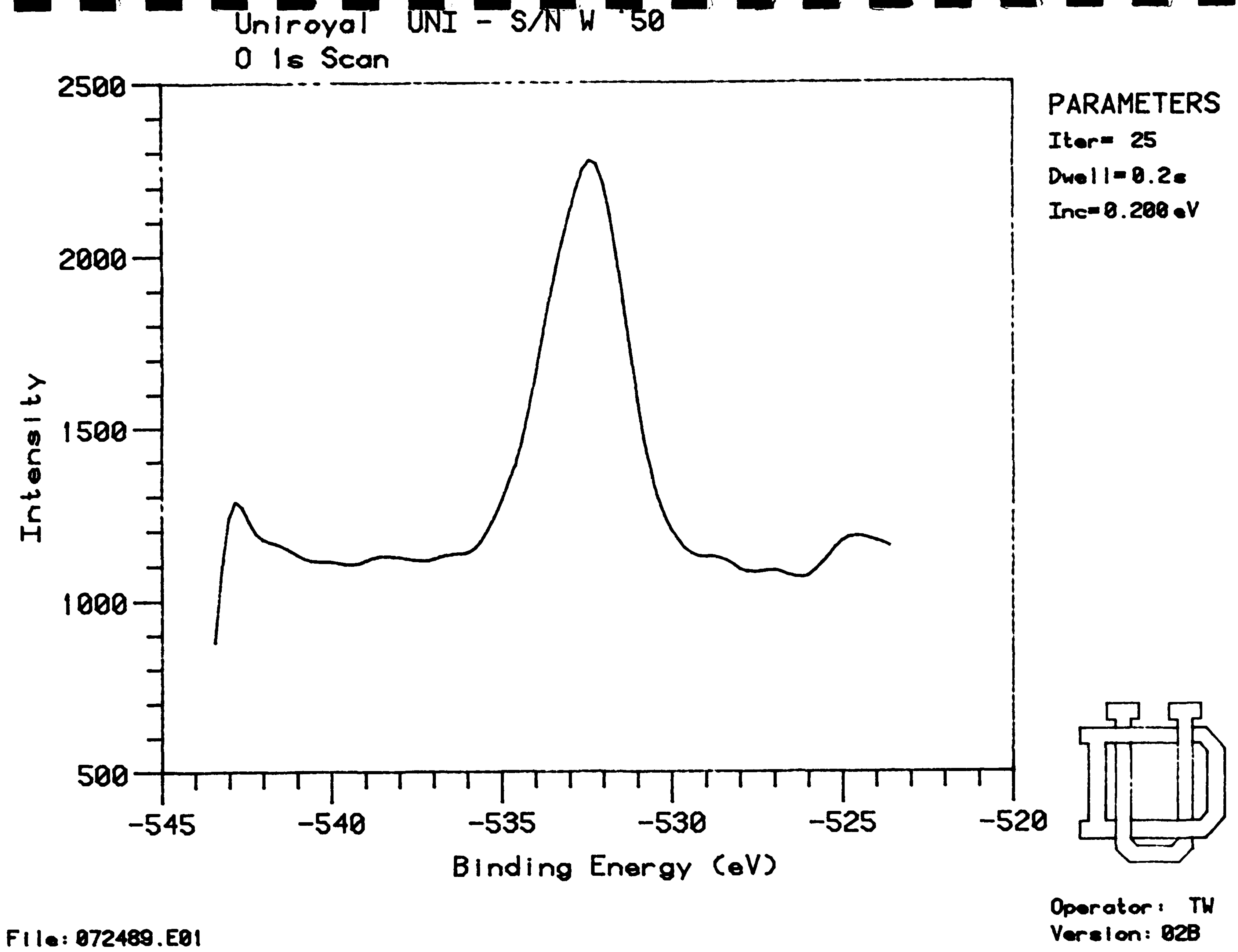


File: 072589.e09

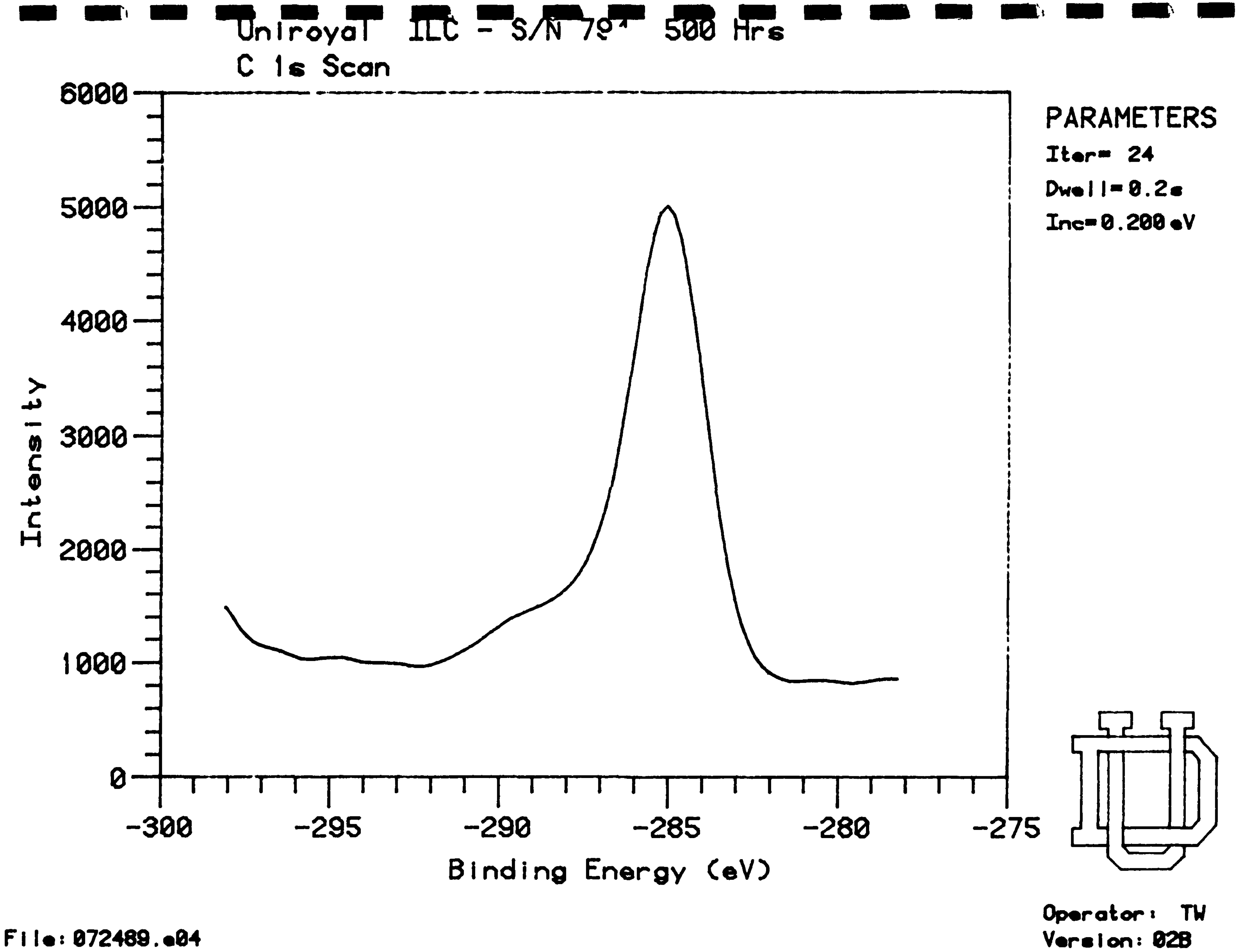
Operator:
Version: 02B



Uniroyal UNI - S/N 1 50
C 1s Scan
6000
5000
4000
3000
2000
1000
0
Intensity
-300
-295
-290
-285
-280
-275
Binding Energy (eV)
PARAMETERS
Iter= 17
Dwell=0.2s
Inc=0.200eV
Operator: TW
Version: 02B
File: 072489.E01

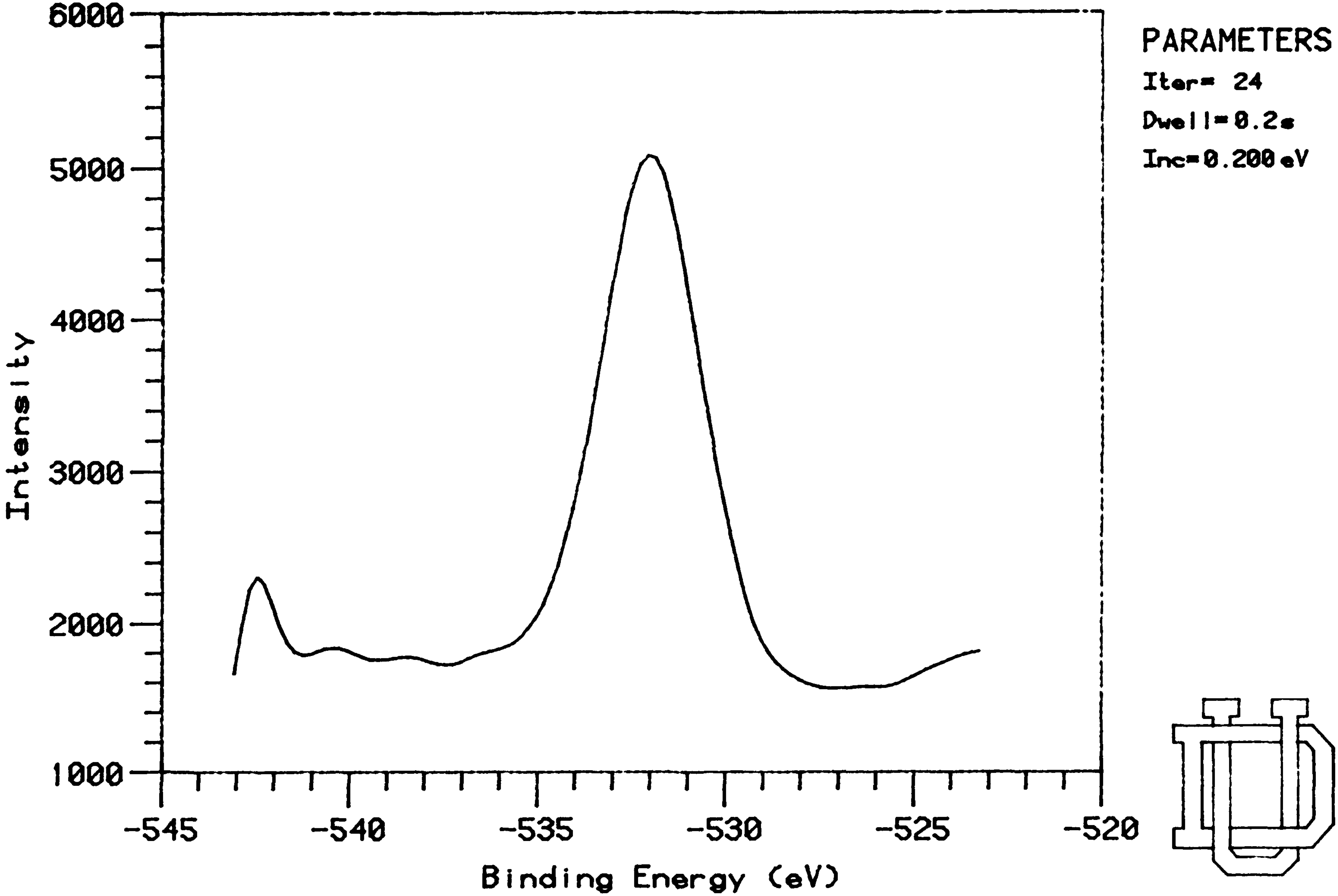


Uniroyal UNI - S/N W 50
O 1s Scan
2500
2000
1500
1000
500
Intensity
-545
-540
-535
-530
-525
-520
Binding Energy (eV)
PARAMETERS
Iter= 25
Dwell=0.2s
Inc=0.200eV
Operator: TW
Version: 02B
File: 072489.E01

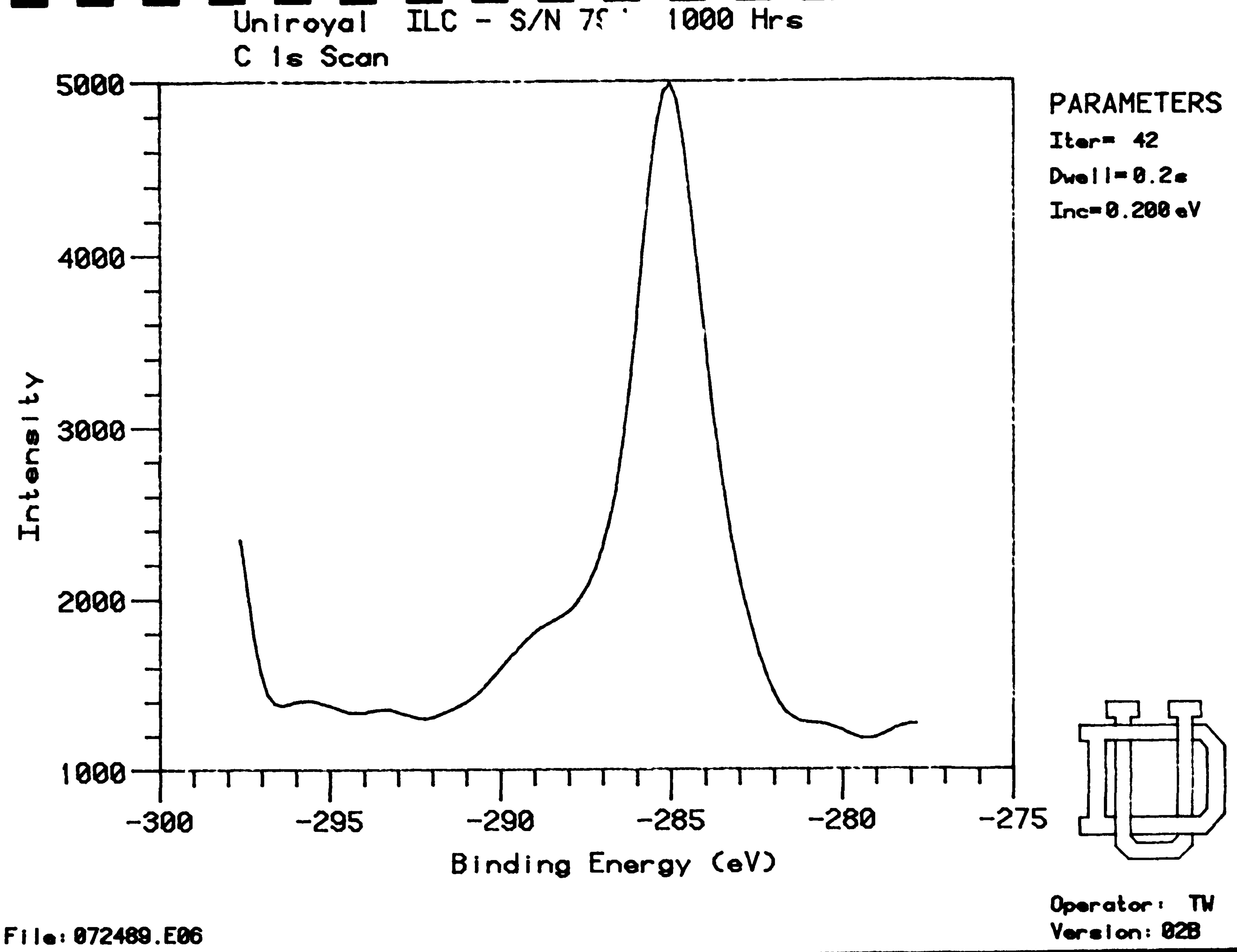

Uniroyal ILC - S/N 7º 500 Hrs
C 1s Scan
Intensity
6000
5000
4000
3000
2000
1000
0
-300
-295
-290
-285
-280
-275
Binding Energy (eV)
PARAMETERS
Iter= 24
Dwell=0.2s
Inc=0.200eV
Operator: TW
Version: 02B
File: 072489.e04

Uniroyal ILC - S/N 79 500 Hrs

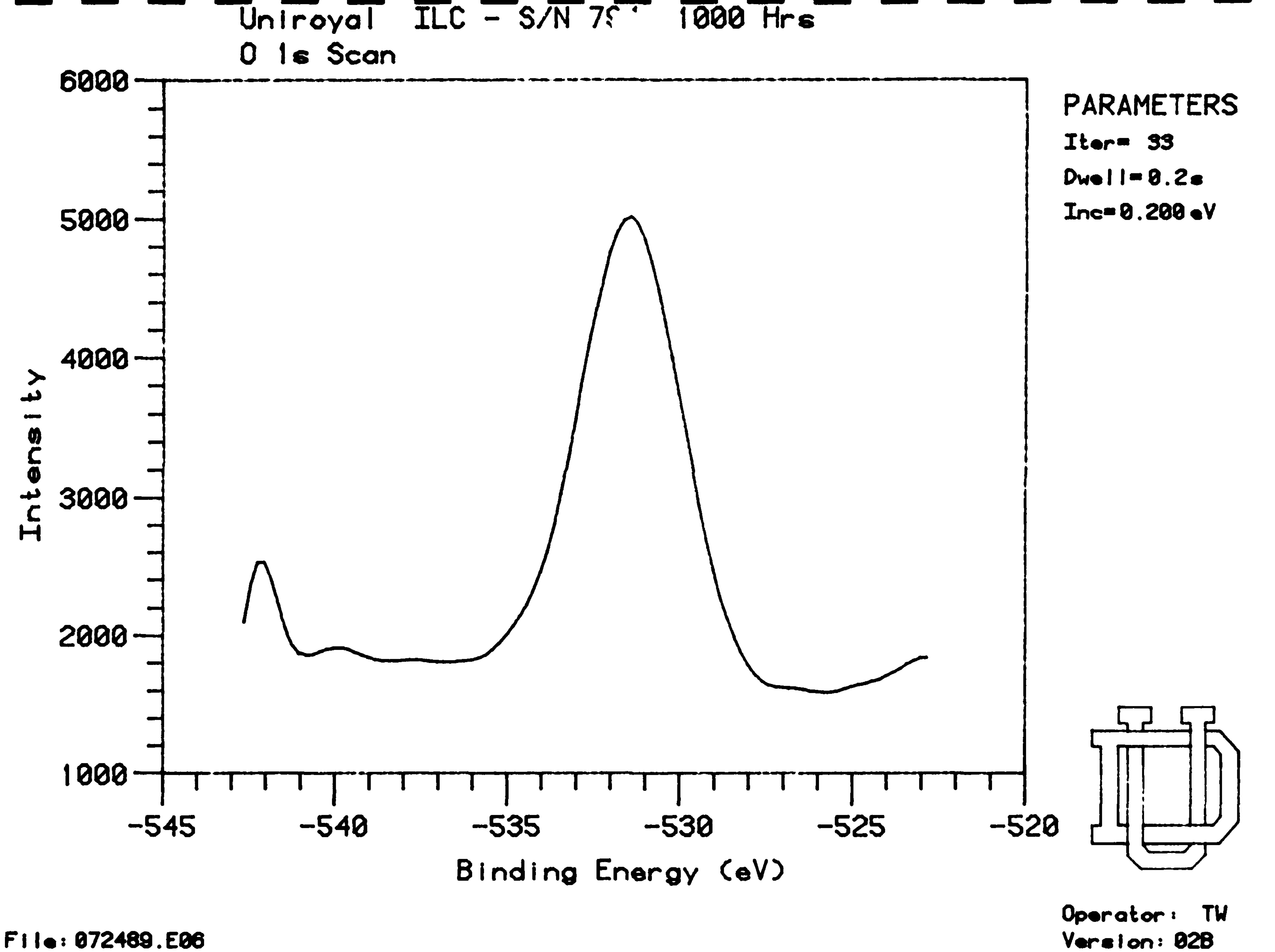
O 1s Scan

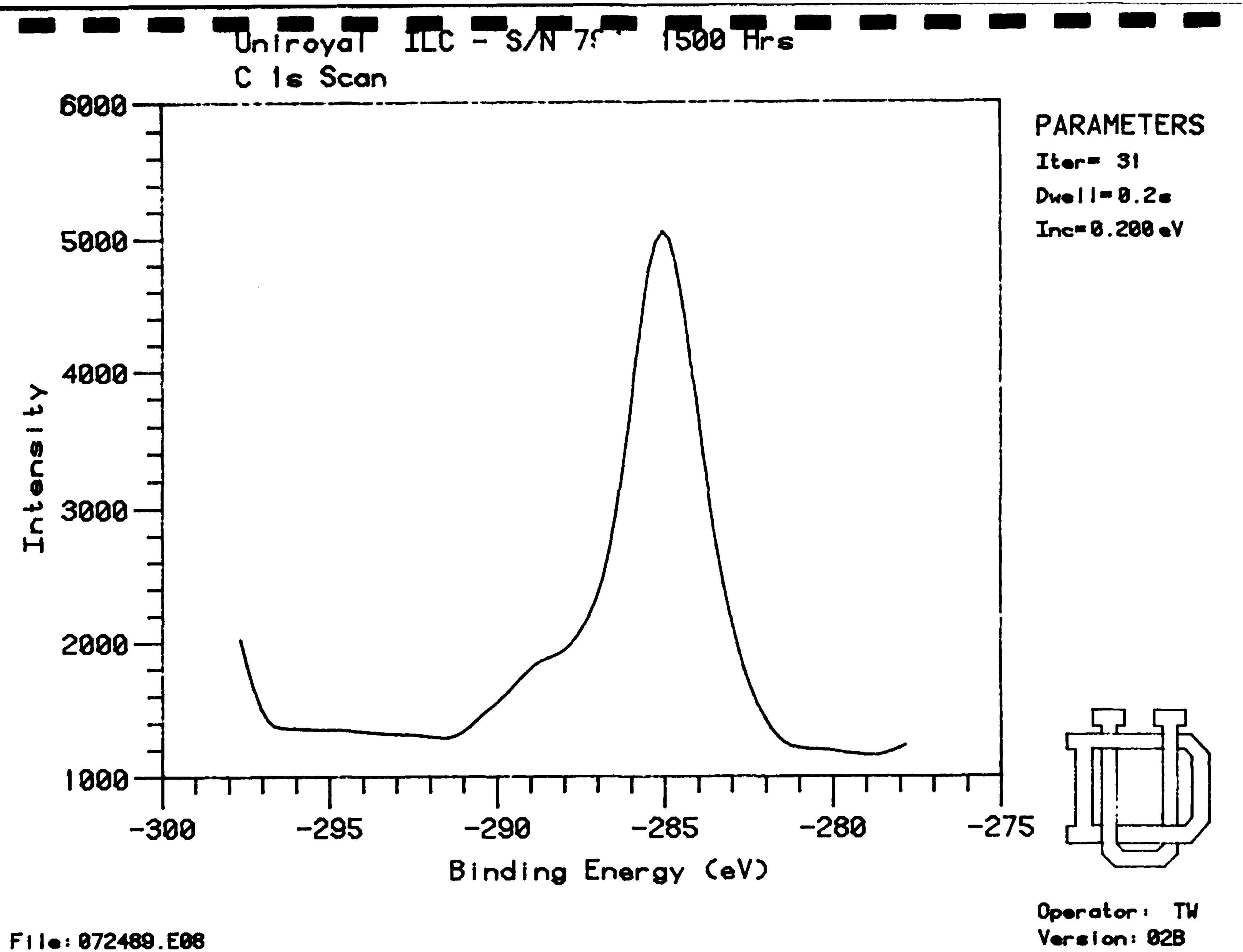


File: 072489.e04



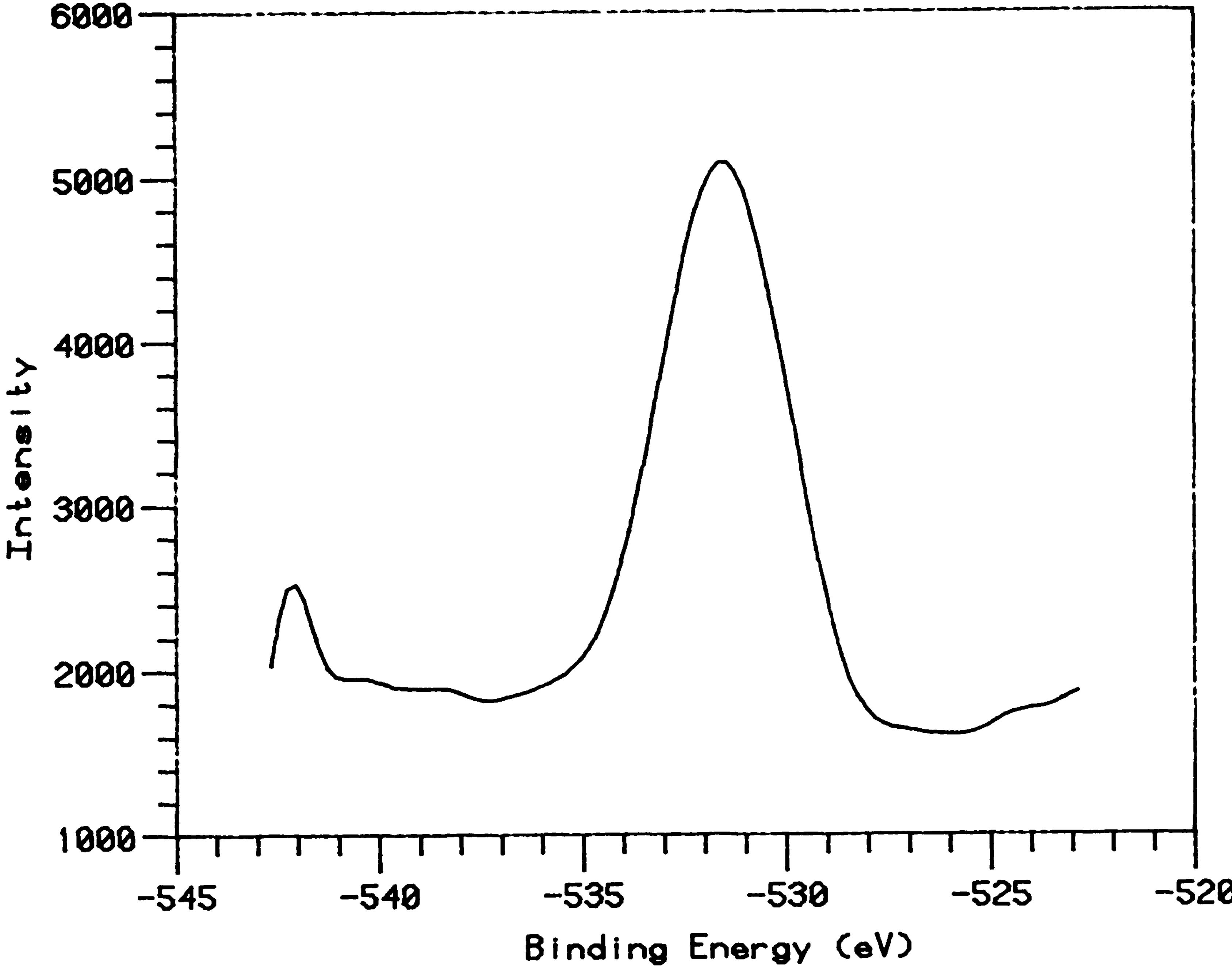
Uniroyal ILC - S/N 7[illegible] 1000 Hrs
C 1s Scan
Intensity
5000
4000
3000
2000
1000
-300
-295
-290
-285
-280
-275
Binding Energy (eV)
PARAMETERS
Iter= 42
Dwell=0.2s
Inc=0.200 eV
Operator: TW
Version: 02B
File: 072489.E06


Uniroyal ILC - S/N 7
1000 Hrs
O 1s Scan
6000
5000
4000
3000
2000
1000
Intensity
-545
-540
-535
-530
-525
-520
Binding Energy (eV)
PARAMETERS
Iter= 33
Dwell=0.2s
Inc=0.200 eV
Operator: TW
Version: 02B
File: 072489.E06



Uniroyal ILC - S/N 7?? 1500 Hrs
C 1s Scan
6000
5000
4000
3000
2000
1000
Intensity
-300
-295
-290
-285
-280
-275
Binding Energy (eV)
PARAMETERS
Iter= 31
Dwell=0.2s
Inc=0.200eV
Operator: TW
Version: 02B
File: 072489.E08

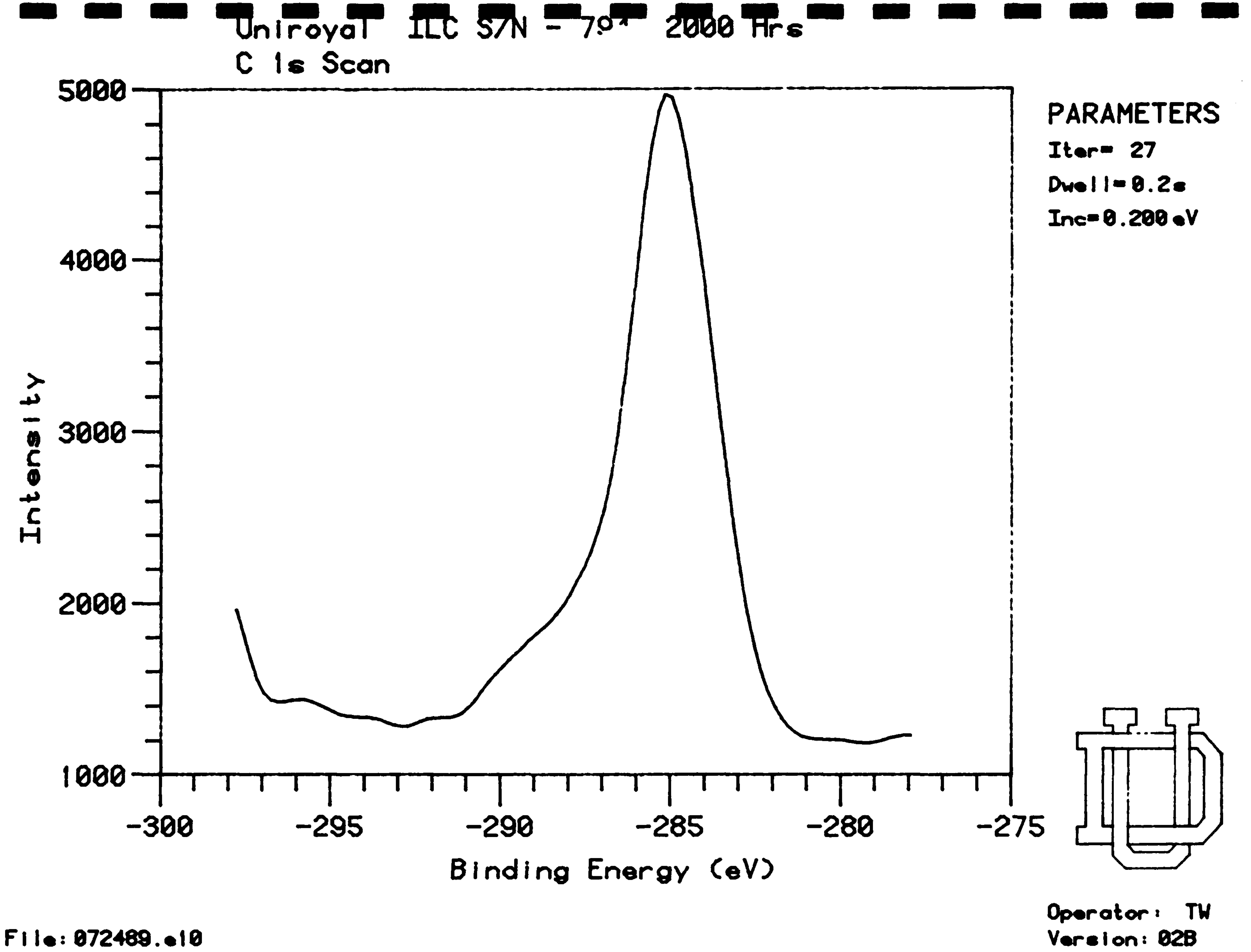
Uniroyal ILC - S/N 7? 1500 Hrs
O 1s Scan



PARAMETERS
Iter= 27
Dwell=0.2s
Inc=0.200eV

Operator: TW
Version: 02B

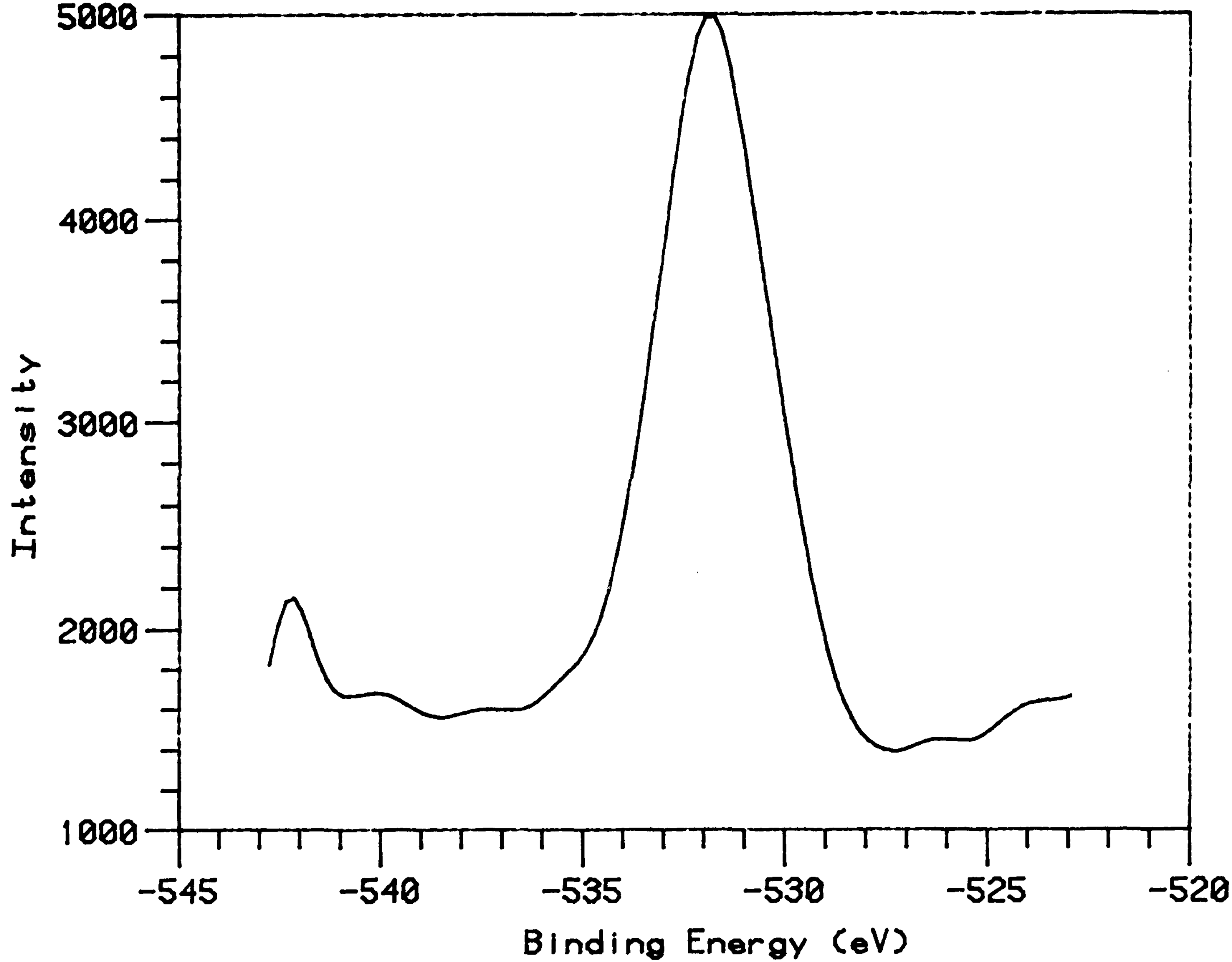
File: 072489.E08



Uniroyal ILC S/N - 79* 2000 Hrs
C 1s Scan
5000
4000
3000
2000
1000
Intensity
-300
-295
-290
-285
-280
-275
Binding Energy (eV)
PARAMETERS
Iter= 27
Dwell=0.2s
Inc=0.200 eV
Operator: TW
Version: 02B
File: 072489.e10

Uniroyal ILC - S/N 79* 2000 Hrs

O 1s Scan



PARAMETERS

Iter= 20

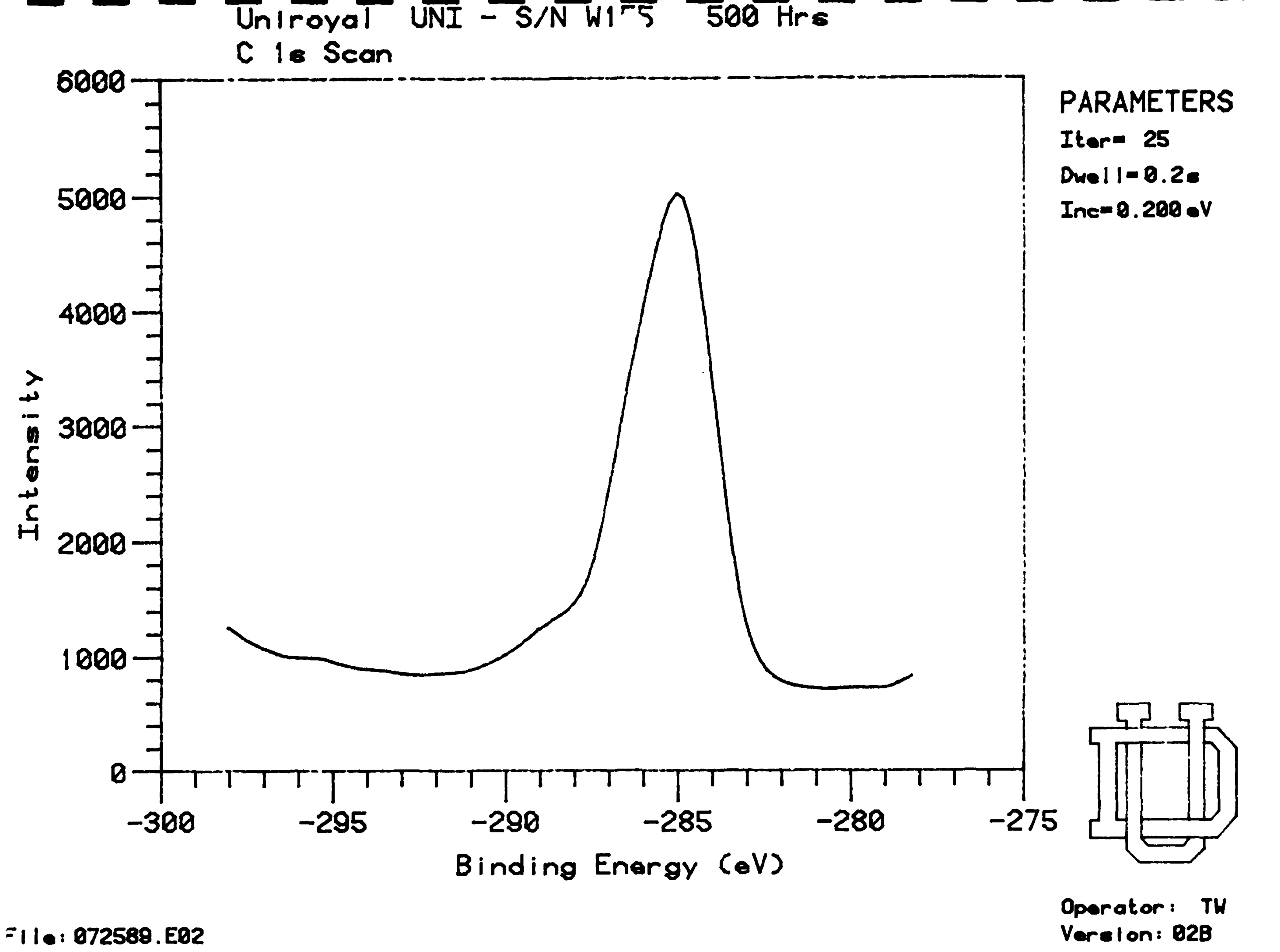
Dwell=0.2s

Inc=0.200 eV

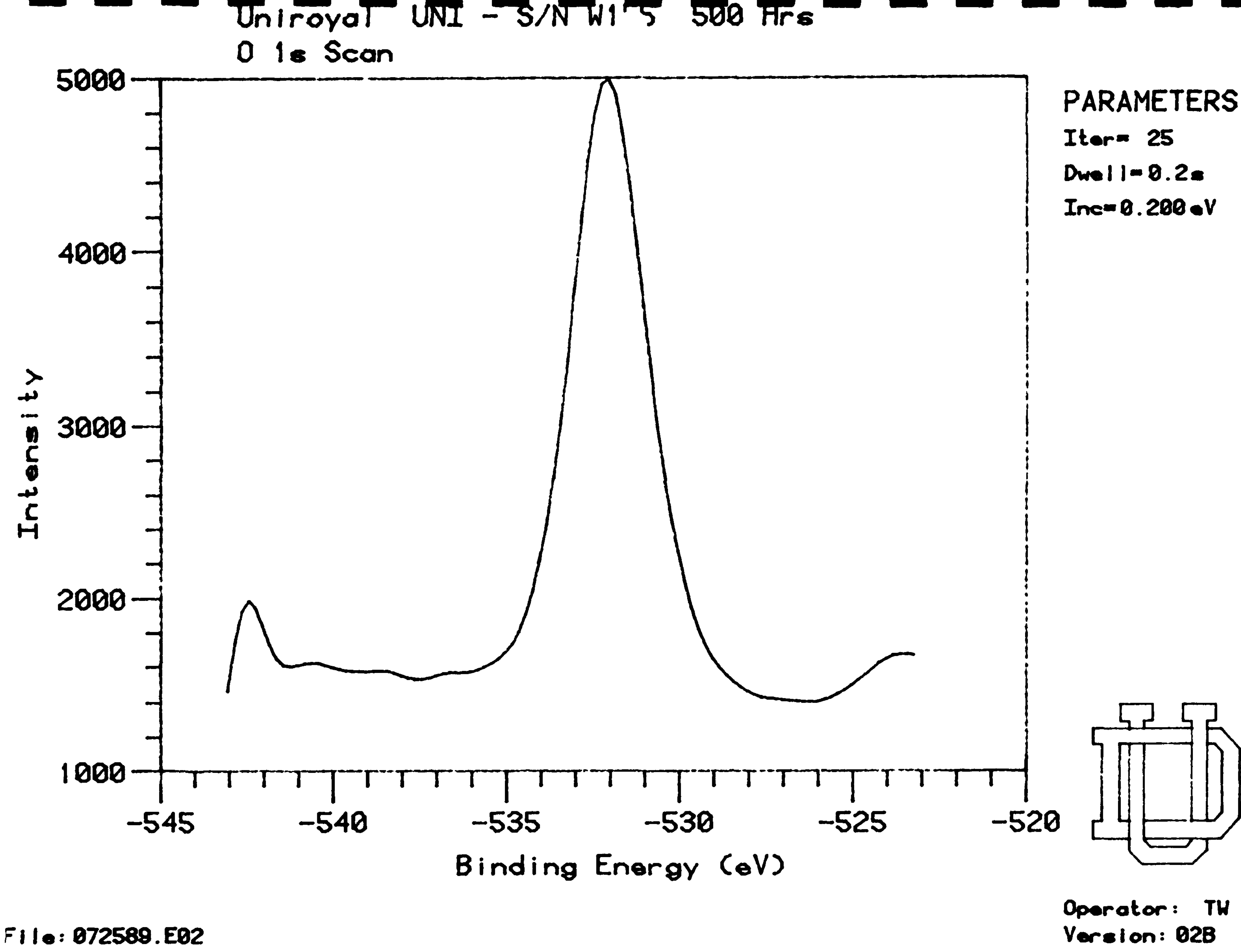
Operator: TW

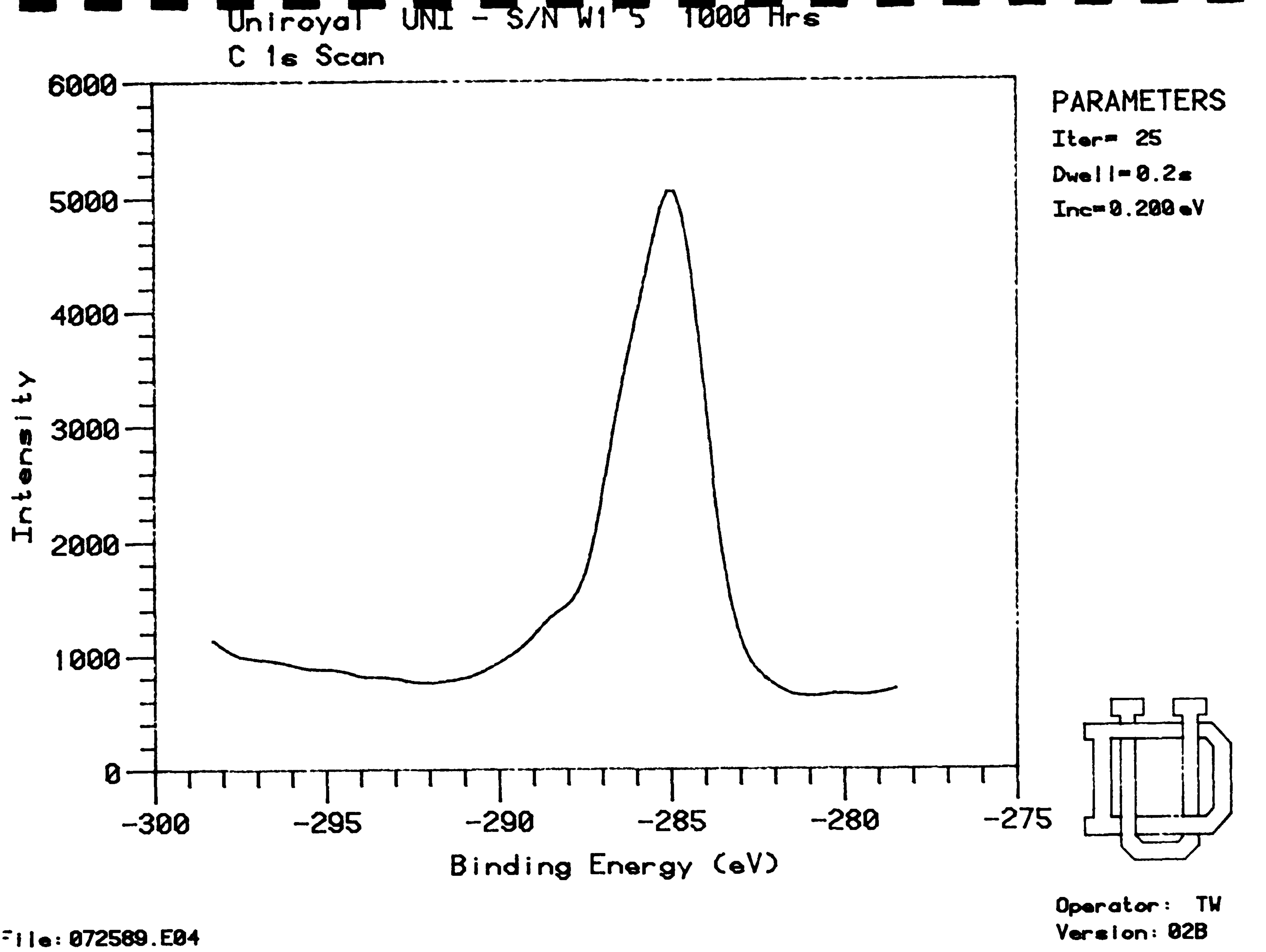
Version: 02B

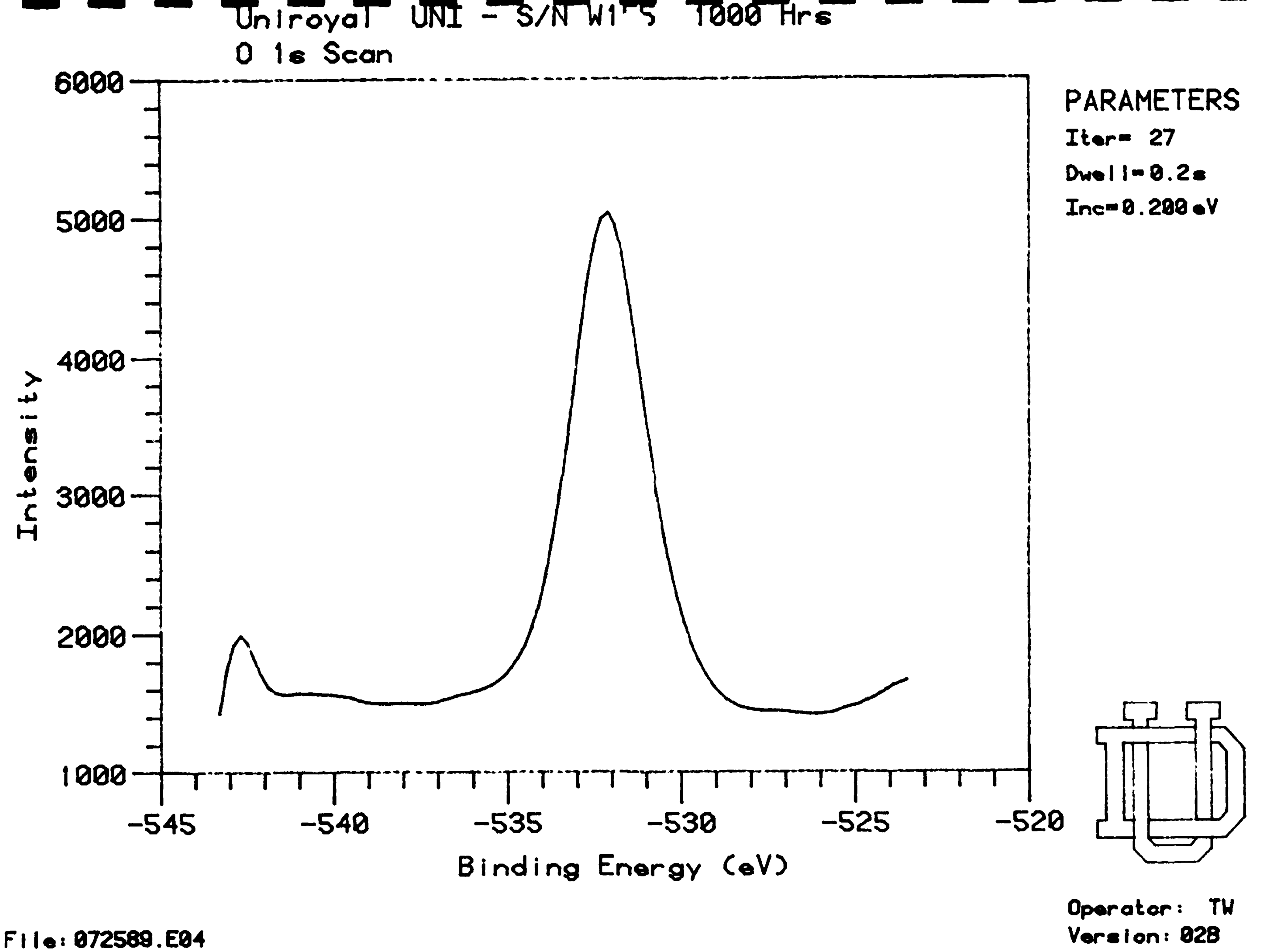
File: 072489.e10



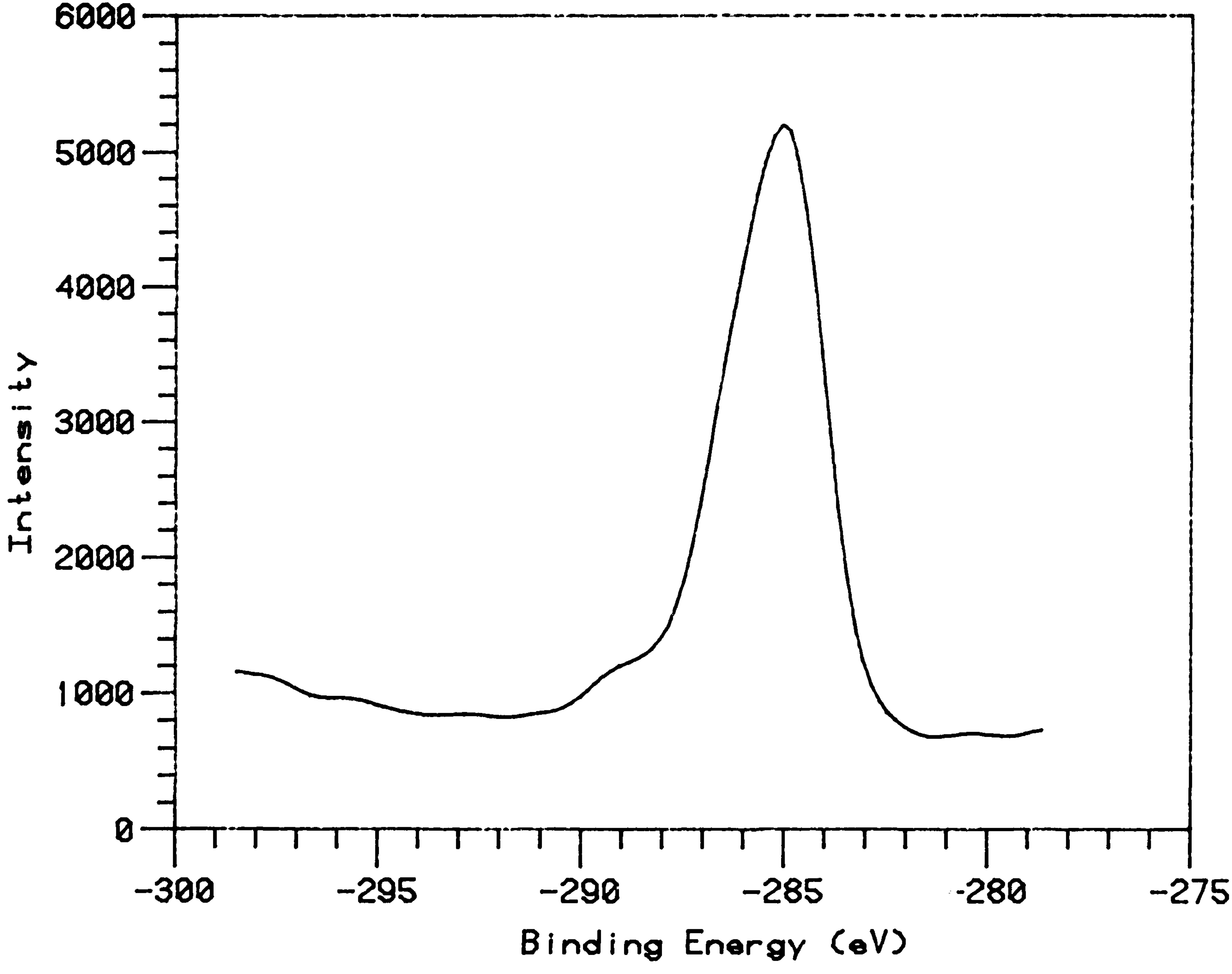
Uniroyal UNI - S/N W1F5 500 Hrs
C 1s Scan
6000
5000
4000
3000
2000
1000
0
Intensity
-300
-295
-290
-285
-280
-275
Binding Energy (eV)
PARAMETERS
Iter= 25
Dwell=0.2s
Inc=0.200eV
Operator: TW
Version: 02B
File: 072589.E02


Uniroyal UNI - S/N W1'5 500 Hrs
O 1s Scan
PARAMETERS
Iter= 25
Dwell=0.2s
Inc=0.200eV
Intensity
5000
4000
3000
2000
1000
-545
-540
-535
-530
-525
-520
Binding Energy (eV)
Operator: TW
Version: 02B
File: 072589.E02


Uniroyal UNI - S/N W1 5 1000 Hrs
C 1s Scan
PARAMETERS
Iter= 25
Dwell=0.2s
Inc=0.200eV
Intensity
6000
5000
4000
3000
2000
1000
0
-300
-295
-290
-285
-280
-275
Binding Energy (eV)
Operator: TW
Version: 02B
File: 072589.E04


Uniroyal UNI - S/N W1'5 1000 Hrs
O 1s Scan
Intensity
6000
5000
4000
3000
2000
1000
-545
-540
-535
-530
-525
-520
Binding Energy (eV)
PARAMETERS
Iter= 27
Dwell=0.2s
Inc=0.200eV
Operator: TW
Version: 02B
File: 072589.E04

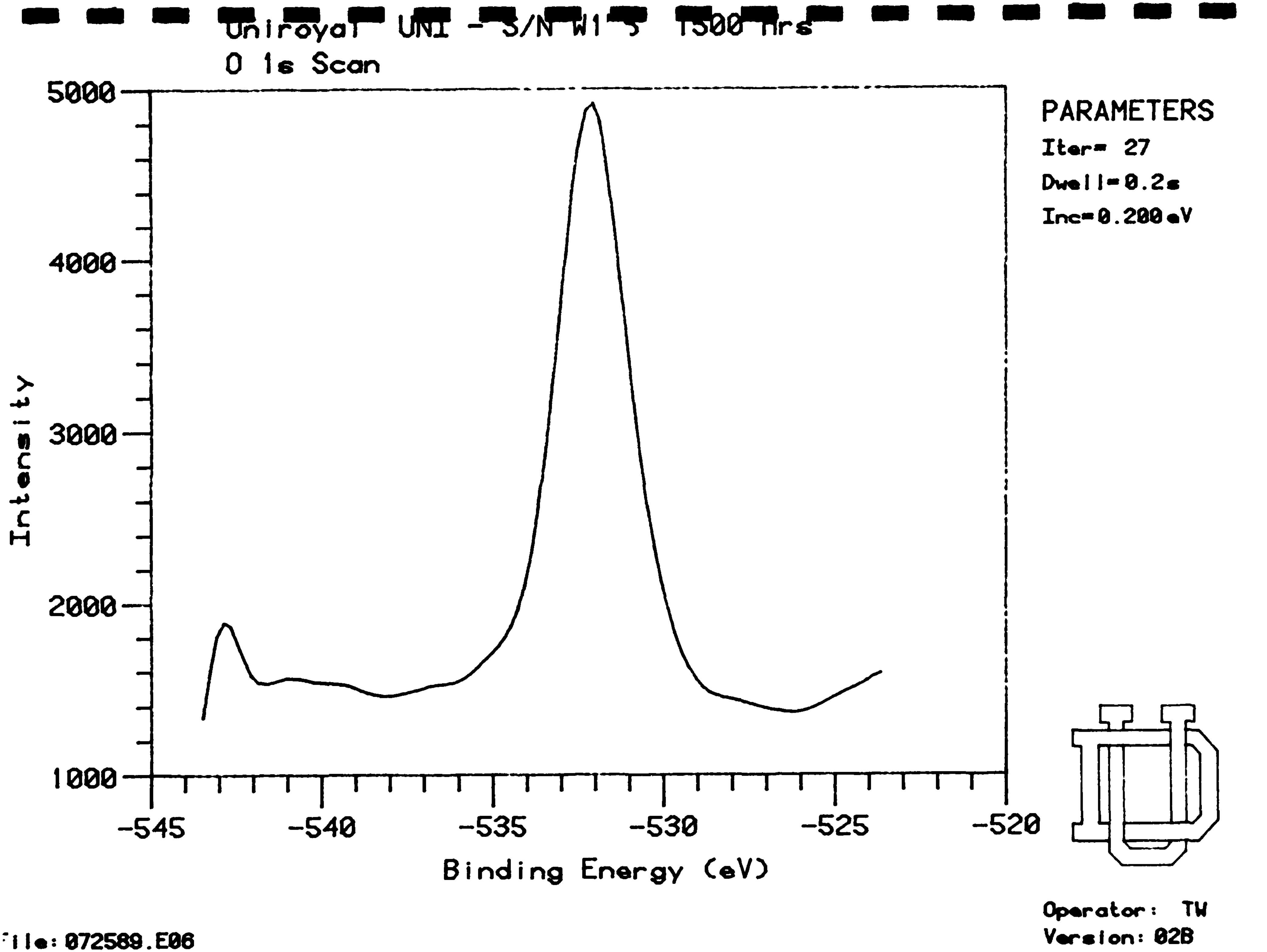
Uniroyal UNI - S/N W1F5 1500 Hrs
C 1s Scan



PARAMETERS
Iter= 26
Dwell=0.2s
Inc=0.200eV

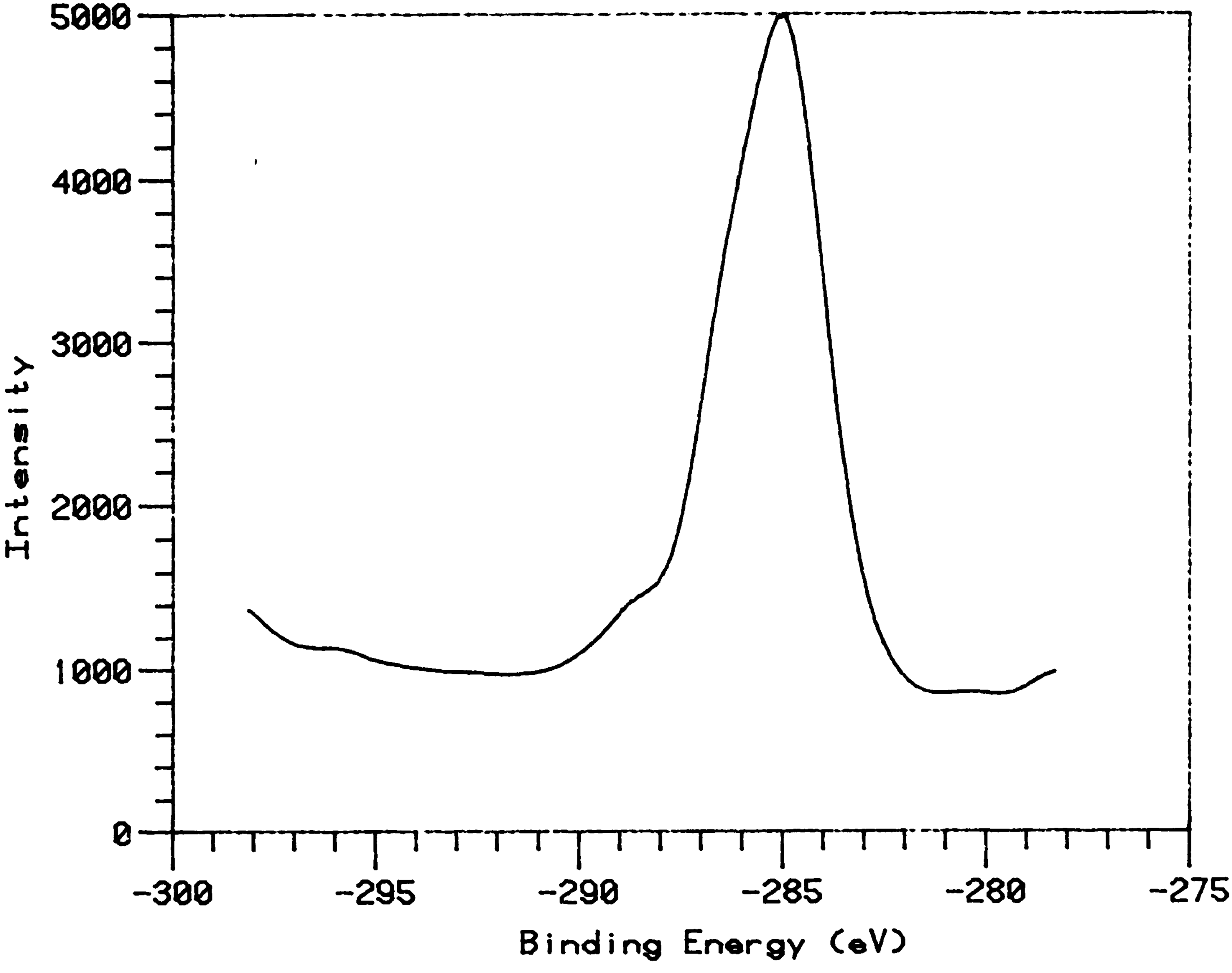
Operator: TW
Version: 02B

File: 072589.E06


Uniroyal UNI - S/N W1 5 T500 hrs
O 1s Scan
PARAMETERS
Iter= 27
Dwell=0.2s
Inc=0.200eV
Intensity
5000
4000
3000
2000
1000
-545
-540
-535
-530
-525
-520
Binding Energy (eV)
Operator: TW
Version: 02B
File: 072589.E06

Uniroyal UNI - S/N W1 5 2000 Hrs

C 1s Scan

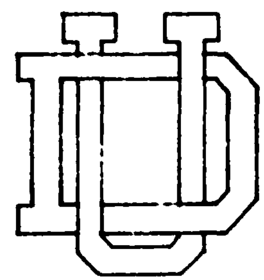


PARAMETERS

Iter= 30

Dwell=0.2s

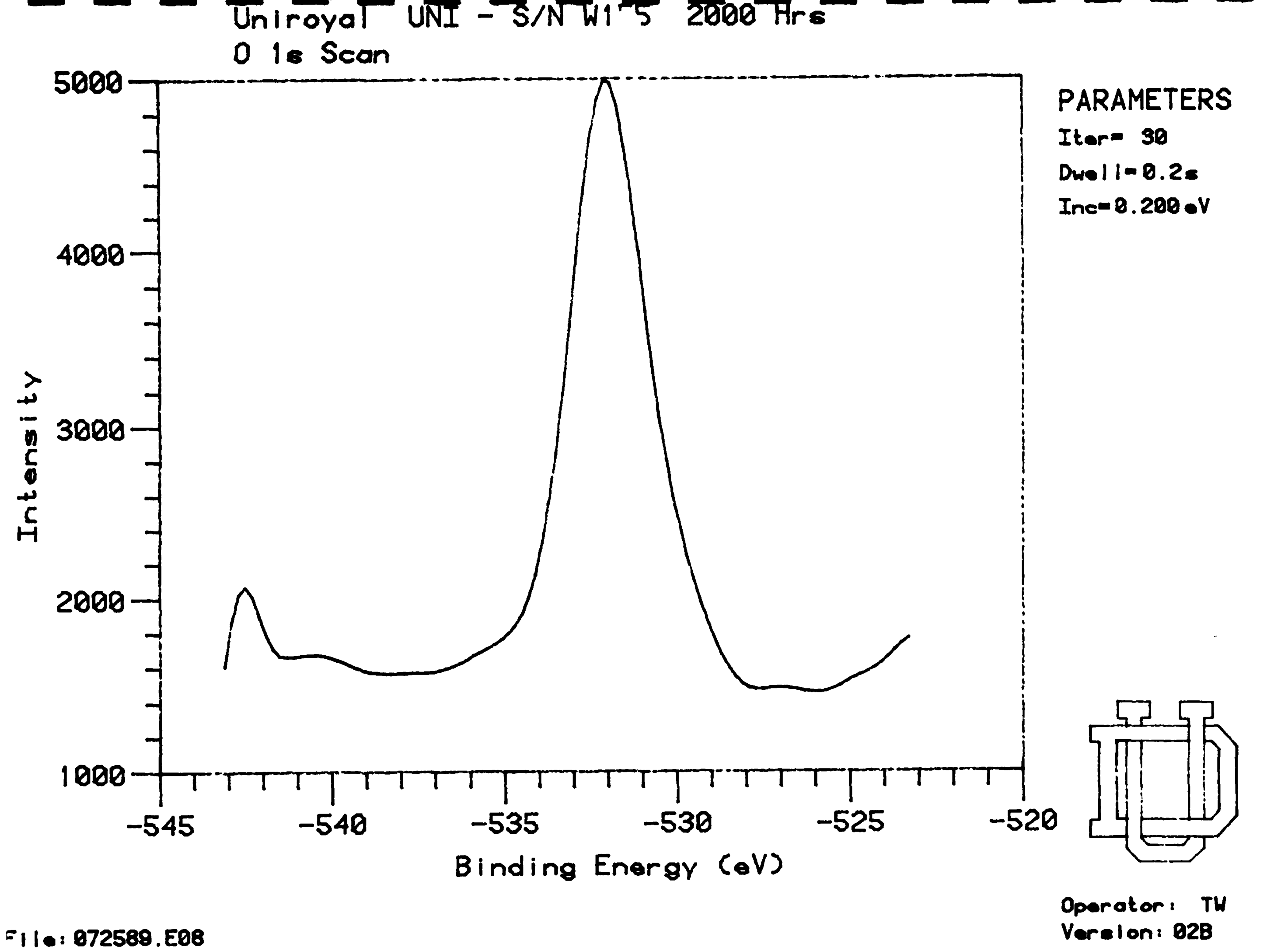
Inc=0.200eV

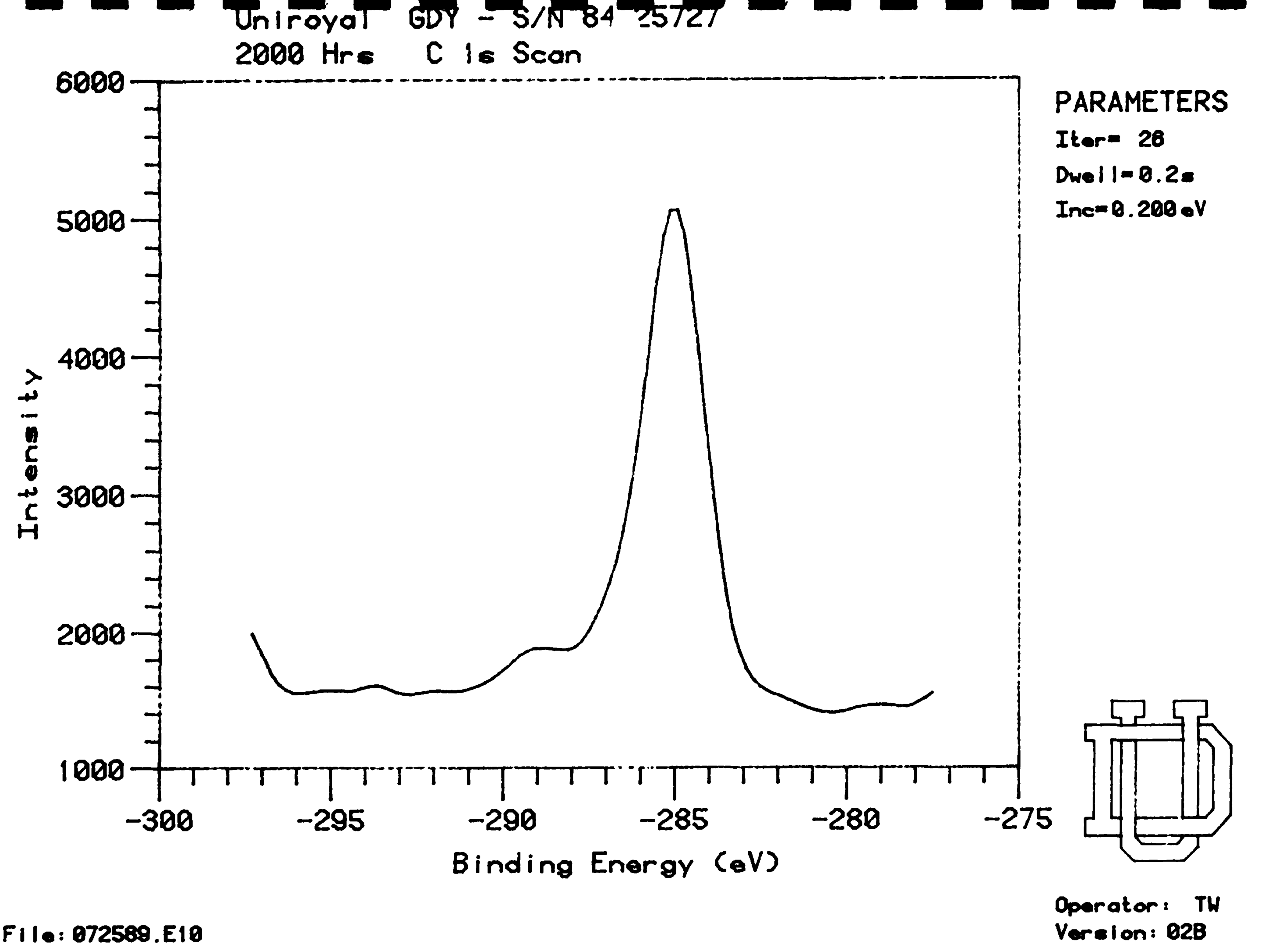


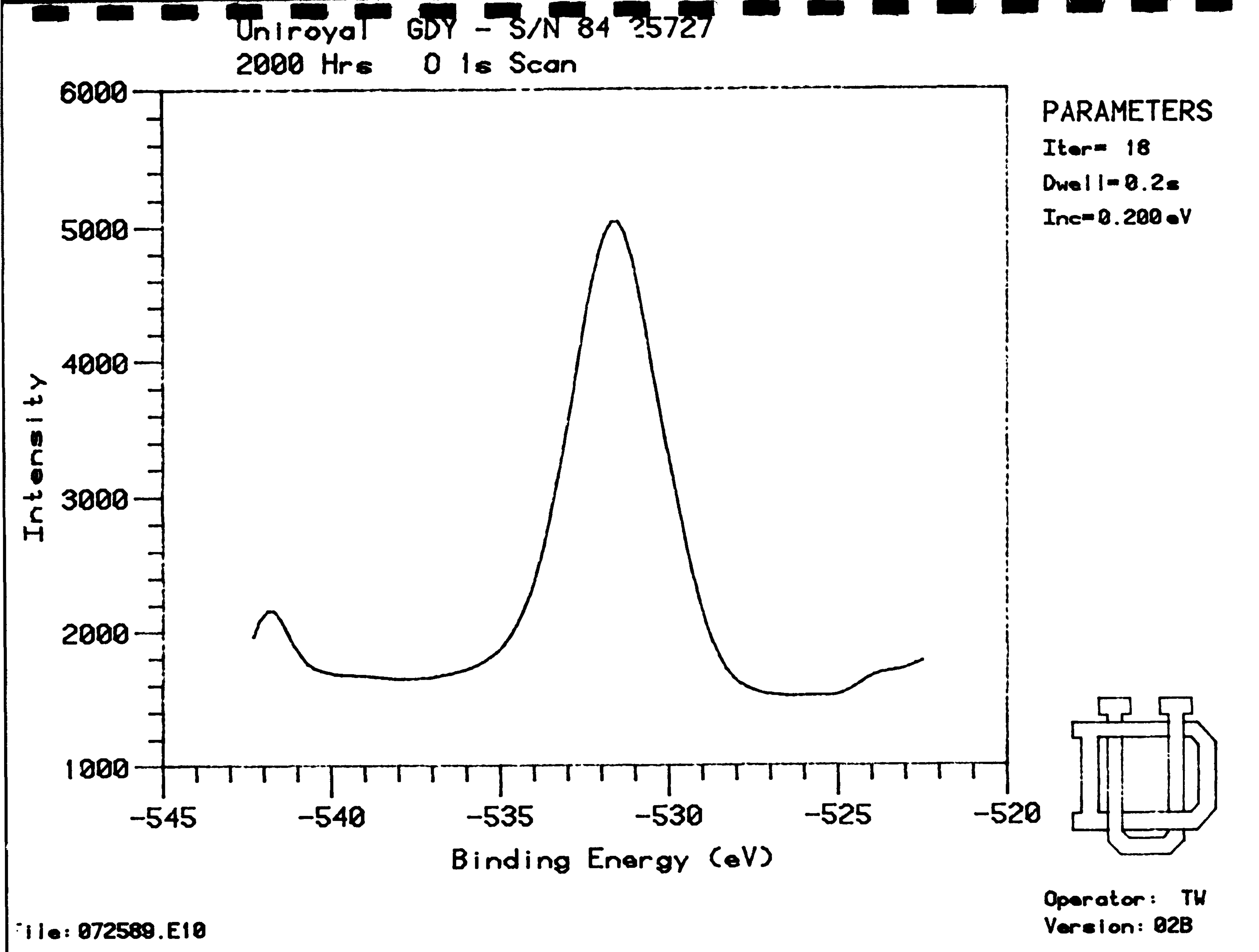
Operator: TW

Version: 02B

File: 072589.E08


Uniroyal UNI - S/N W1 5 2000 Hrs
O 1s Scan
5000
4000
3000
2000
1000
Intensity
-545
-540
-535
-530
-525
-520
Binding Energy (eV)
PARAMETERS
Iter= 30
Dwell=0.2s
Inc=0.200eV
Operator: TW
Version: 02B
File: 072589.E08


Uniroyal GDY - S/N 84 25727
2000 Hrs C 1s Scan
Intensity
6000
5000
4000
3000
2000
1000
-300
-295
-290
-285
-280
-275
Binding Energy (eV)
PARAMETERS
Iter= 26
Dwell=0.2s
Inc=0.200eV
Operator: TW
Version: 02B
File: 072589.E10


Uniroyal GDY - S/N 84 25727
2000 Hrs O 1s Scan
Intensity
6000
5000
4000
3000
2000
1000
-545
-540
-535
-530
-525
-520
Binding Energy (eV)
PARAMETERS
Iter= 18
Dwell=0.2s
Inc=0.200eV
Operator: TW
Version: 02B
File: 072589.E10

The University of Dayton

24 October 1988

Mr. G. E. Colley
Uniroyal Plastics Company
312 North Hill Street
P.O. Box 2000
Mishawaka, IN 46544

Dear Mr. Colley:

I have used XPS to analyze the six elastomer samples that you sent to Jim Hoenigman last week. The following table gives the measured carbon/oxygen atom % ratios for the surfaces of interest.

Sample	% Carbon/% Oxygen
UNI-5439 #2222	4.6
UNI-5444	6.4
UNI-SN W150 (aged 1000 hrs)	4.9
UNI-SN W150 (aged 1500 hrs)	3.3
GDY-SN84-25727 (aged 1000 hrs)	0.87
GDY-SN84-25727 (aged 1500 hrs)	1.35

I have included a survey scan for each sample. In some cases this scan shows that other elements such as chlorine, silicon, nitrogen and calcium are detected in addition to carbon and oxygen. I have also included high resolution scans of the carbon 1s and oxygen 1s peaks for each sample. In some cases the carbon 1s peak shows strong shoulders due to C-O or C=O bonded carbon.

Please let me know if you have any questions about these results.

Sincerely,

Tom Wittberg

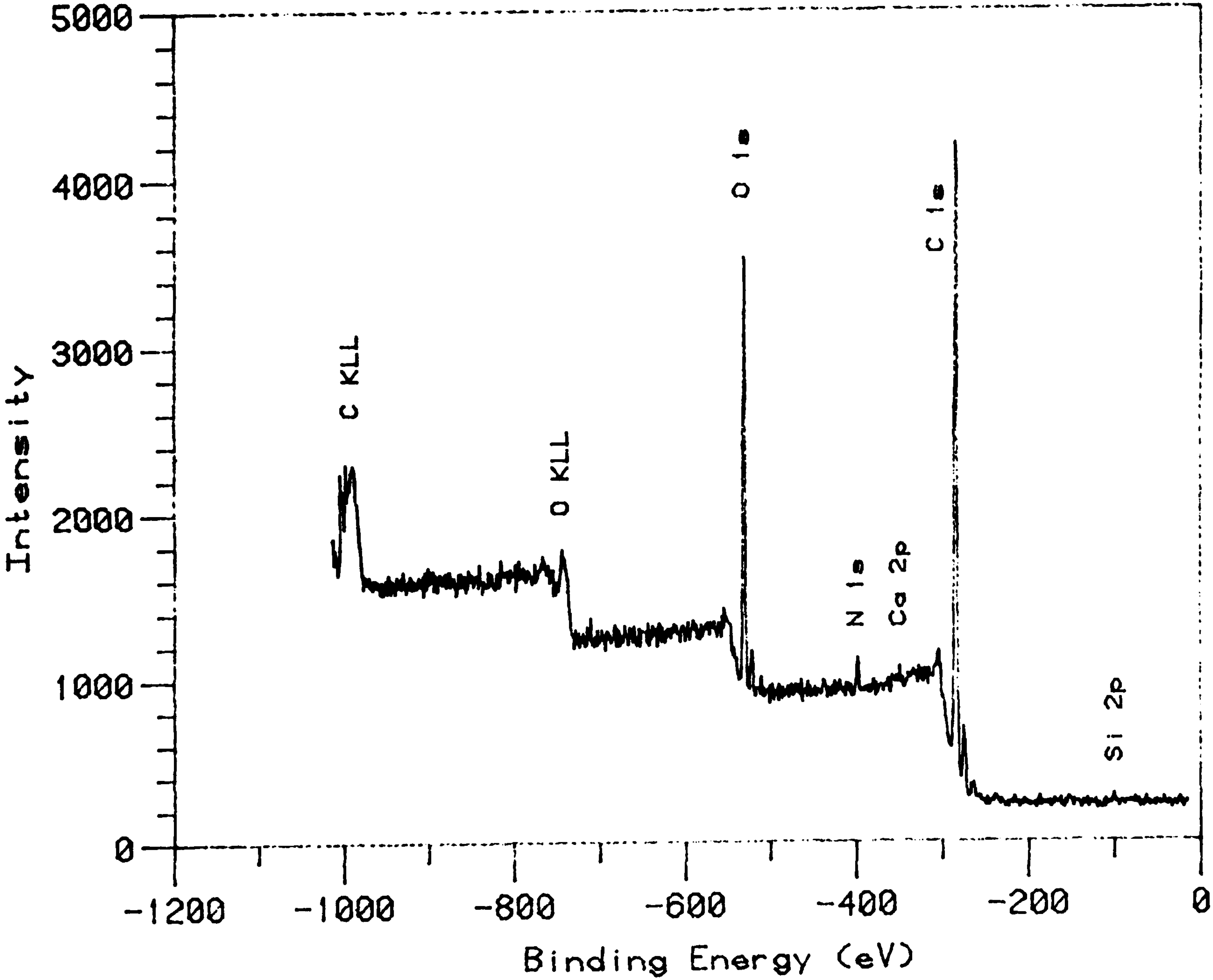
Tom Wittberg

TW:prc

Enclosures

UNIROYAL UNI-5439 #2222

XPS Survey Scan



PARAMETERS

Iter= 12

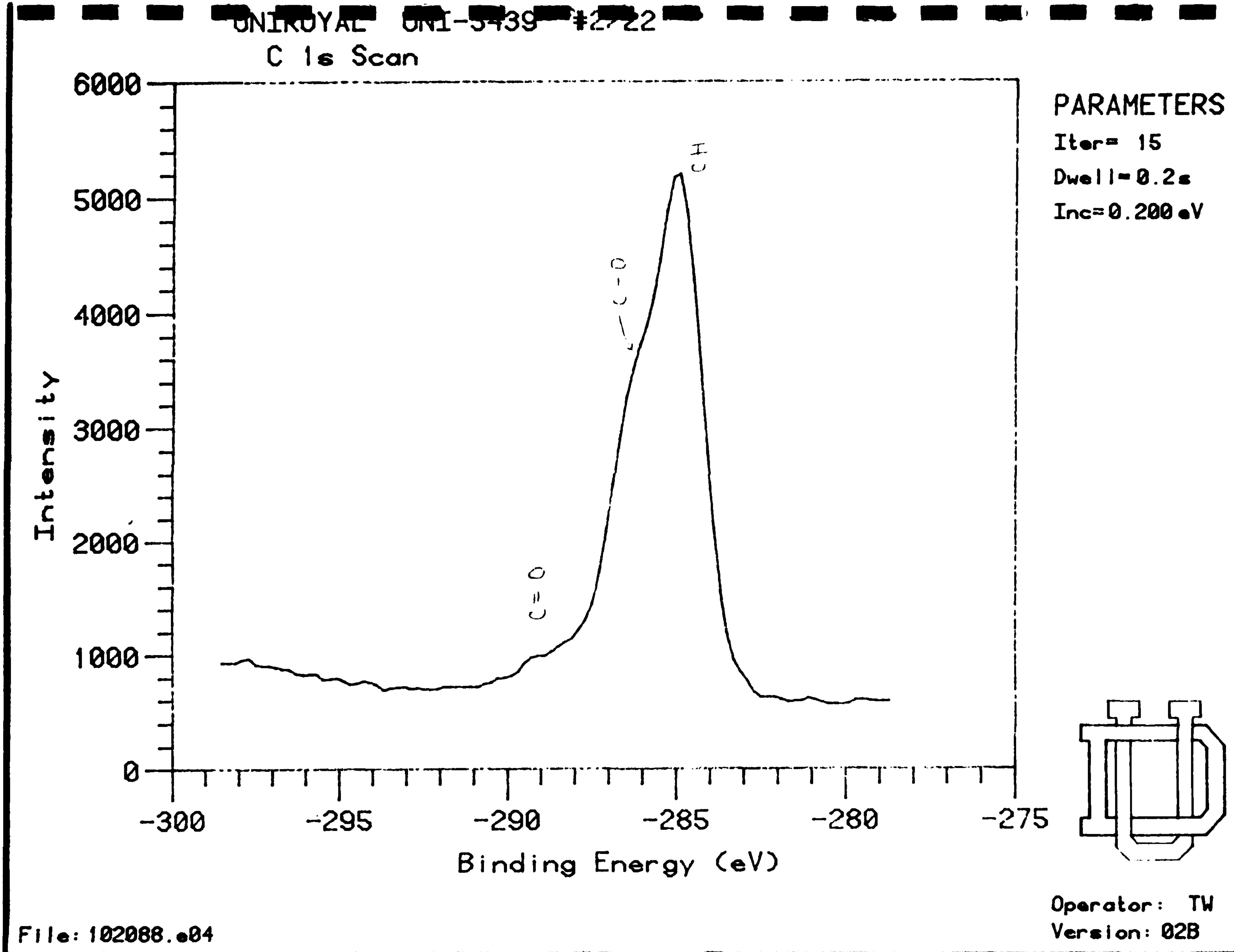
Dwell=0.1s

Inc=1.000eV

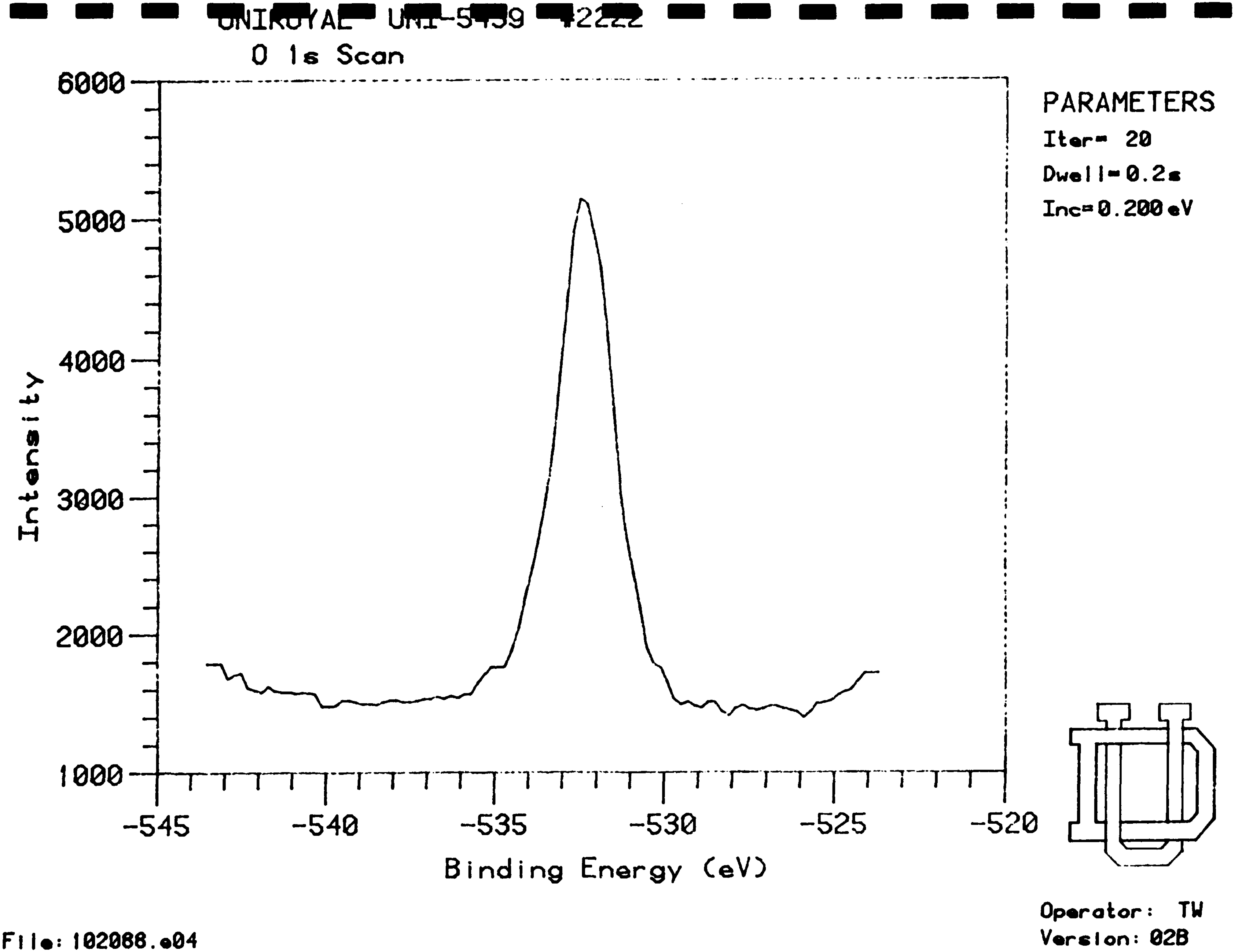
Operator: TW

Version: 02B

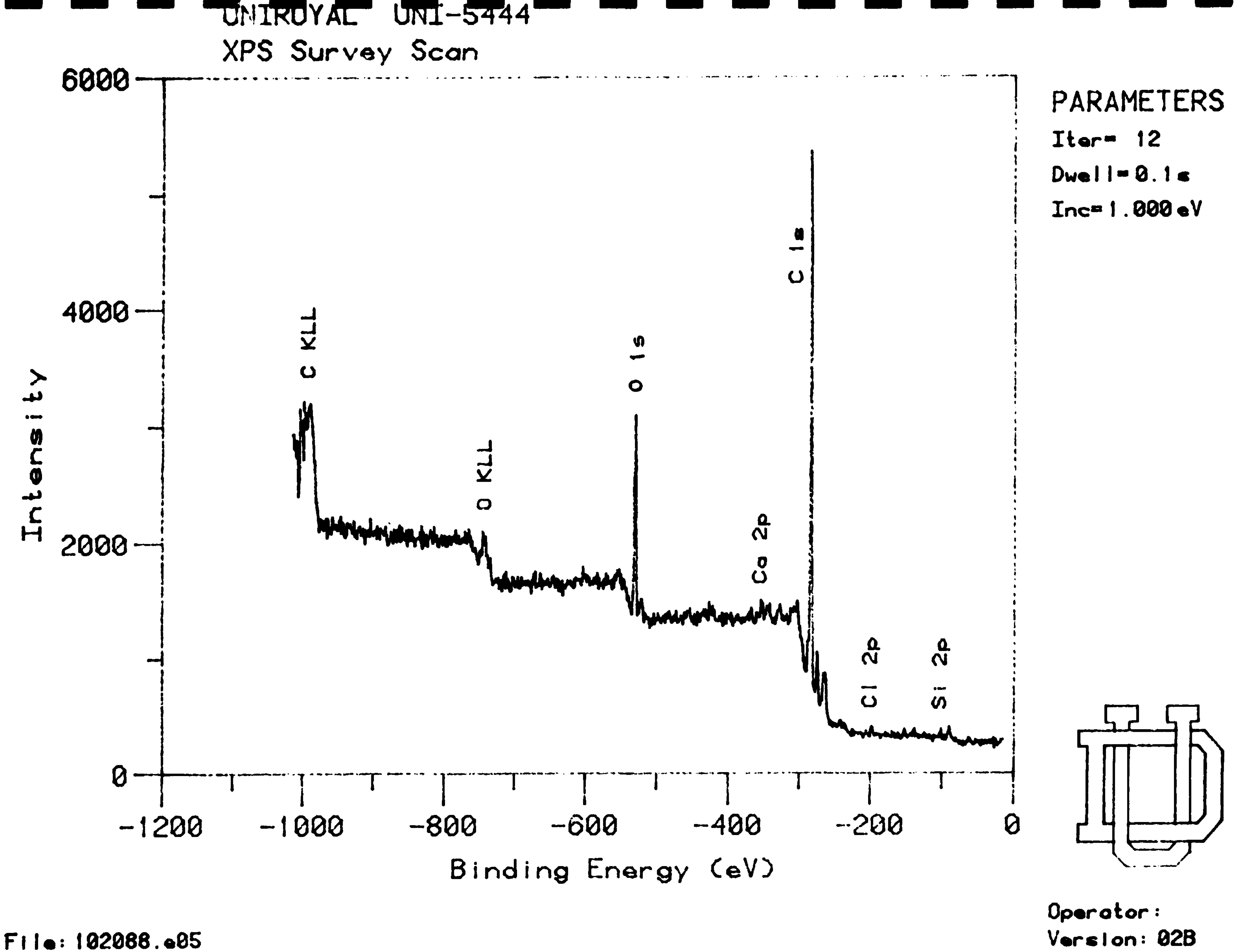
File: 102088.e03

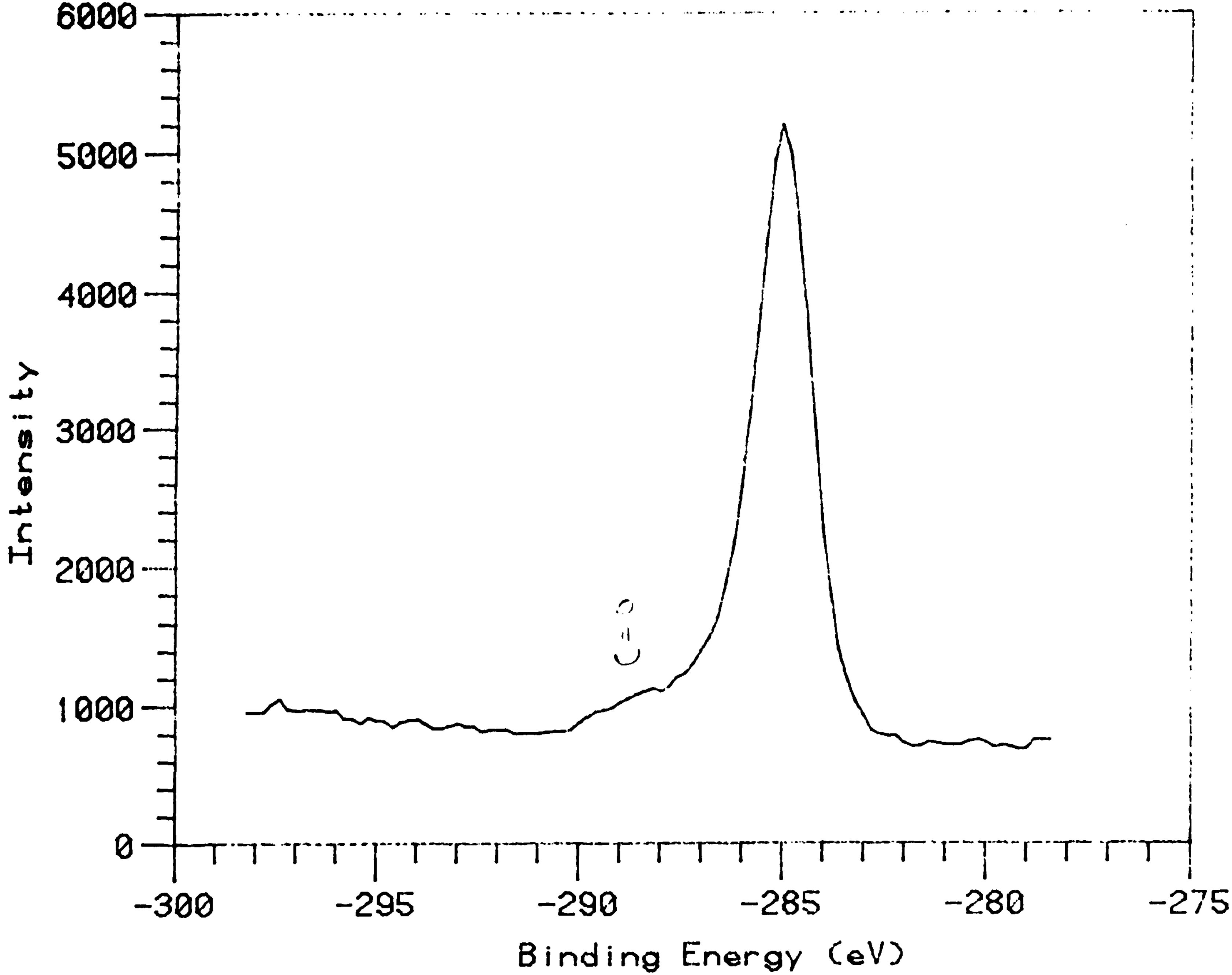


UNIROYAL UNI-5439 #2722
C 1s Scan
6000
5000
4000
3000
2000
1000
0
Intensity
C H
C - O
C = O
-300
-295
-290
-285
-280
-275
Binding Energy (eV)
PARAMETERS
Iter= 15
Dwell=0.2s
Inc=0.200eV
Operator: TW
Version: 02B
File: 102088.e04



UNIROYAL UNI-5439 #2222
O 1s Scan
6000
5000
4000
3000
2000
1000
Intensity
-545
-540
-535
-530
-525
-520
Binding Energy (eV)
PARAMETERS
Iter= 20
Dwell=0.2s
Inc=0.200eV
Operator: TW
Version: 02B
File: 102088.e04

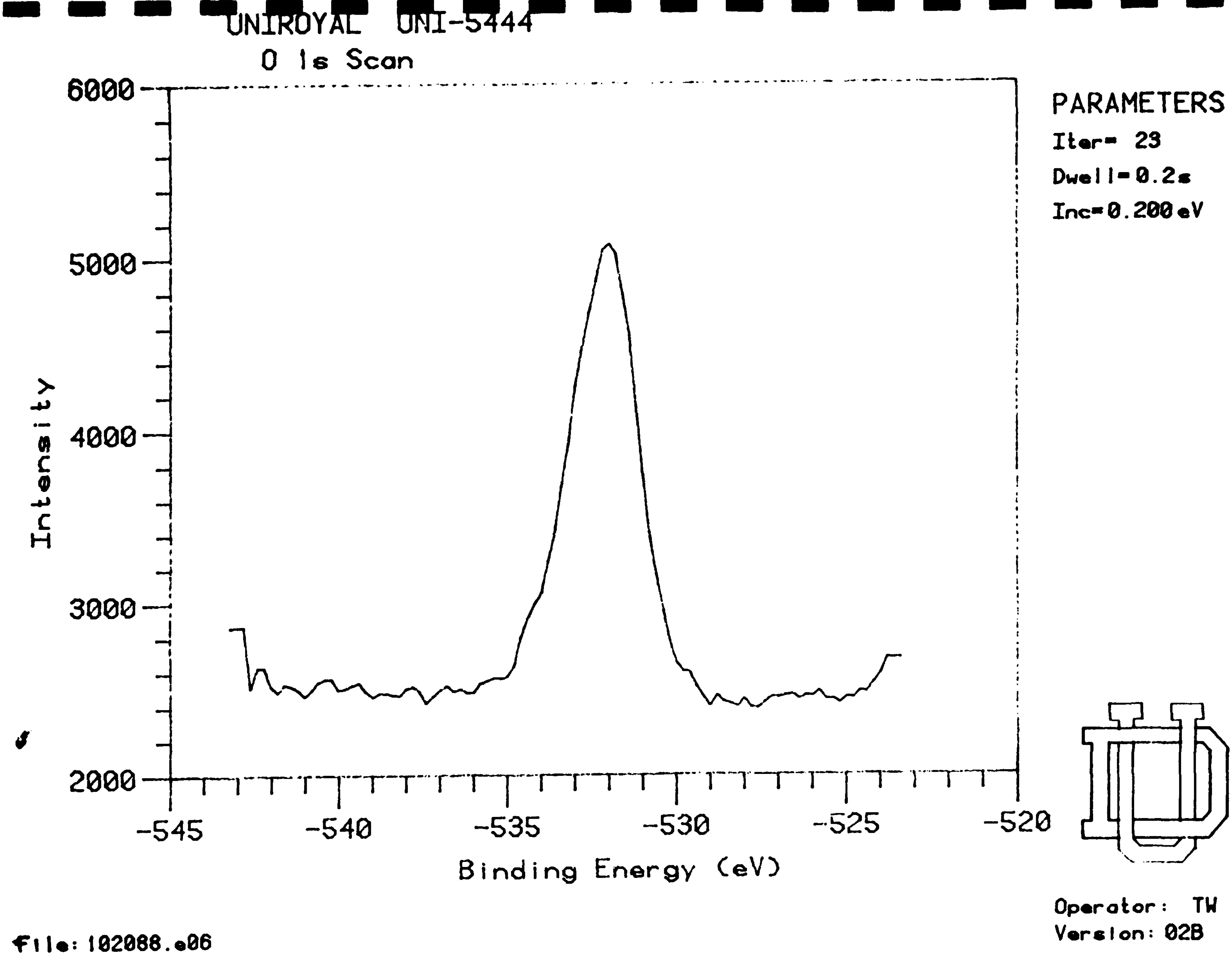

UNIROYAL UNI-5444
XPS Survey Scan
Intensity
6000
4000
2000
0
-1200
-1000
-800
-600
-400
-200
0
Binding Energy (eV)
C KLL
O KLL
O 1s
Ca 2p
C 1s
Cl 2p
Si 2p
PARAMETERS
Iter= 12
Dwell=0.1s
Inc=1.000eV
Operator:
Version: 02B
File: 102088.e05



PARAMETERS
Iter= 11
Dwell=0.2s
Inc=0.200eV

Operator: TW
Version: 02B

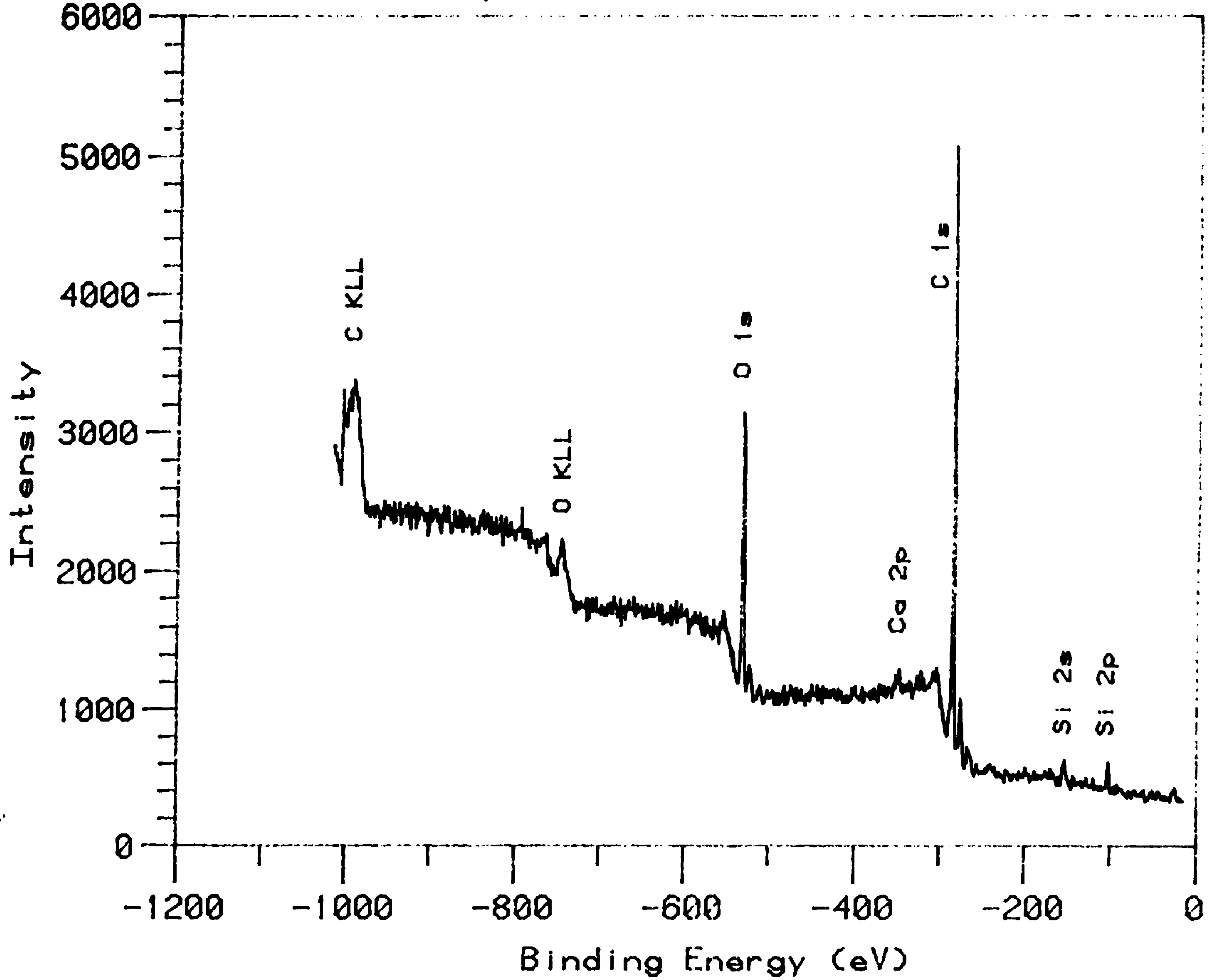
File: 102088.e06



UNIROYAL UNI-5444
O 1s Scan
6000
5000
4000
3000
2000
Intensity
-545
-540
-535
-530
-525
-520
Binding Energy (eV)
PARAMETERS
Iter= 23
Dwell=0.2s
Inc=0.200eV
Operator: TW
Version: 02B
File: 102088.e06

UNIROYAL UNI-SN WT50 (Aged 1000 Hrs)

XPS Survey Scan



PARAMETERS

Iter= 11

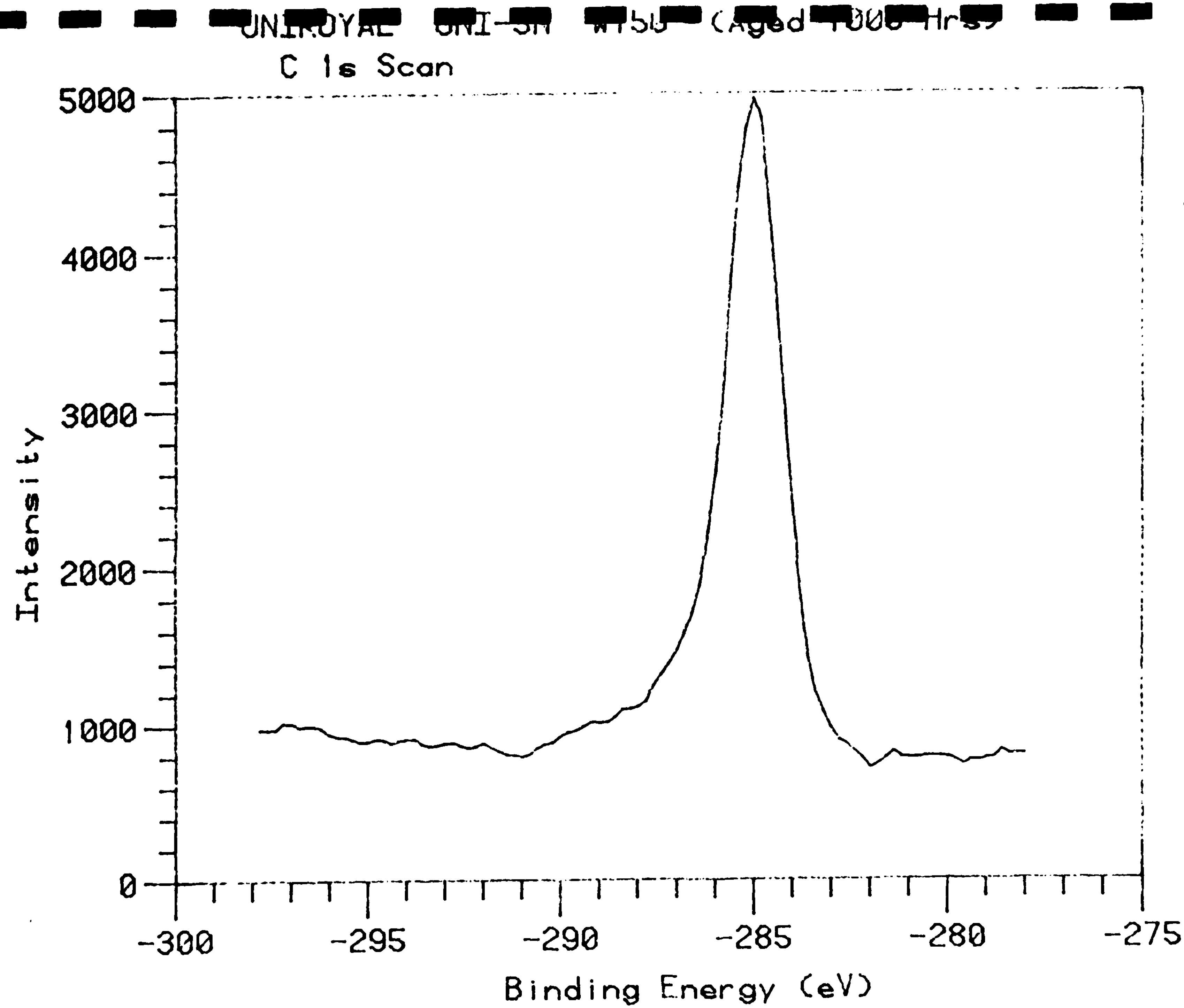
Dwell=0.1s

Inc=1.000eV

Operator: TW

Version: 02B

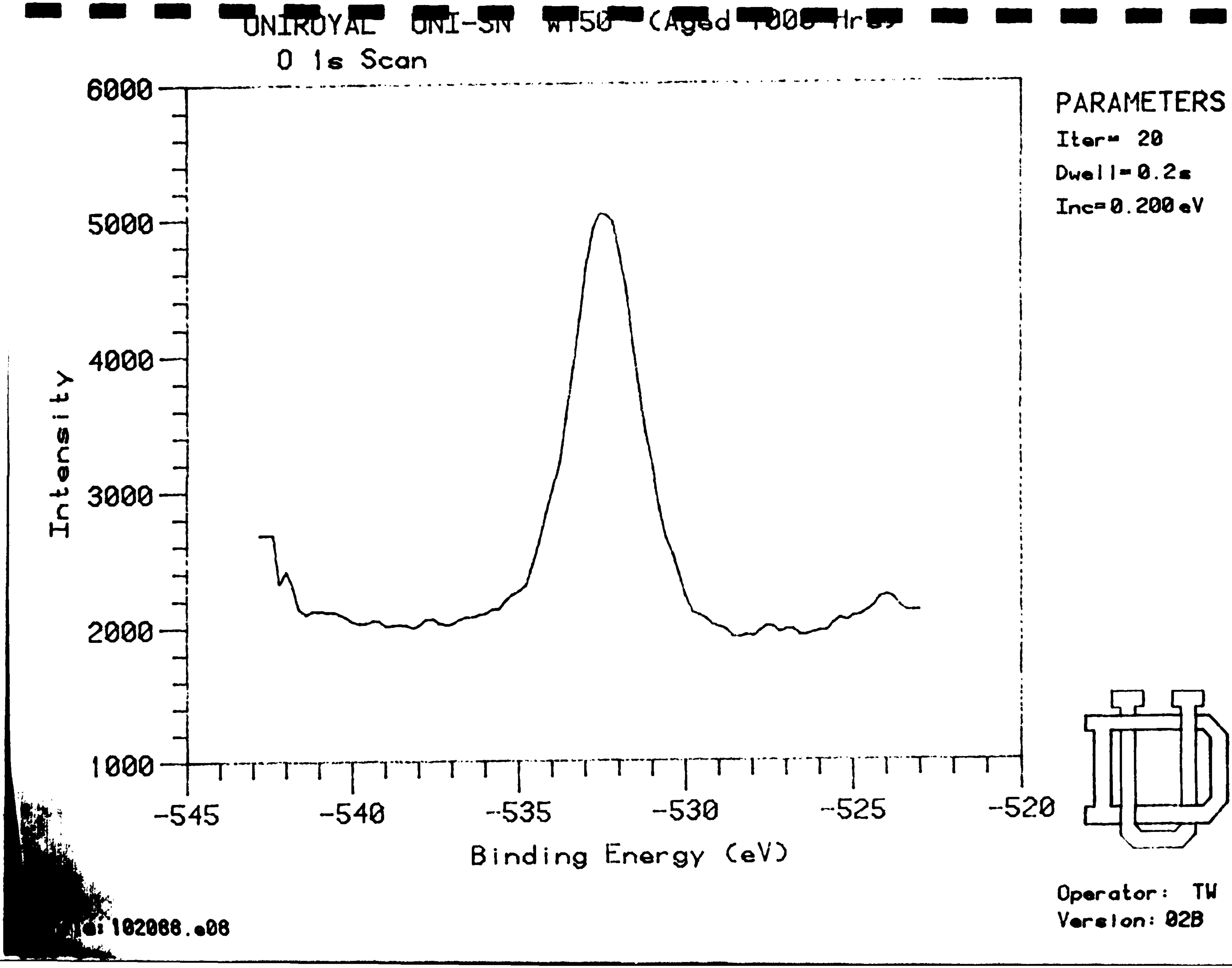
File: 102088.e07



PARAMETERS
Iter= 11
Dwell=0.2s
Inc=0.200eV

Operator: TW
Version: 02B

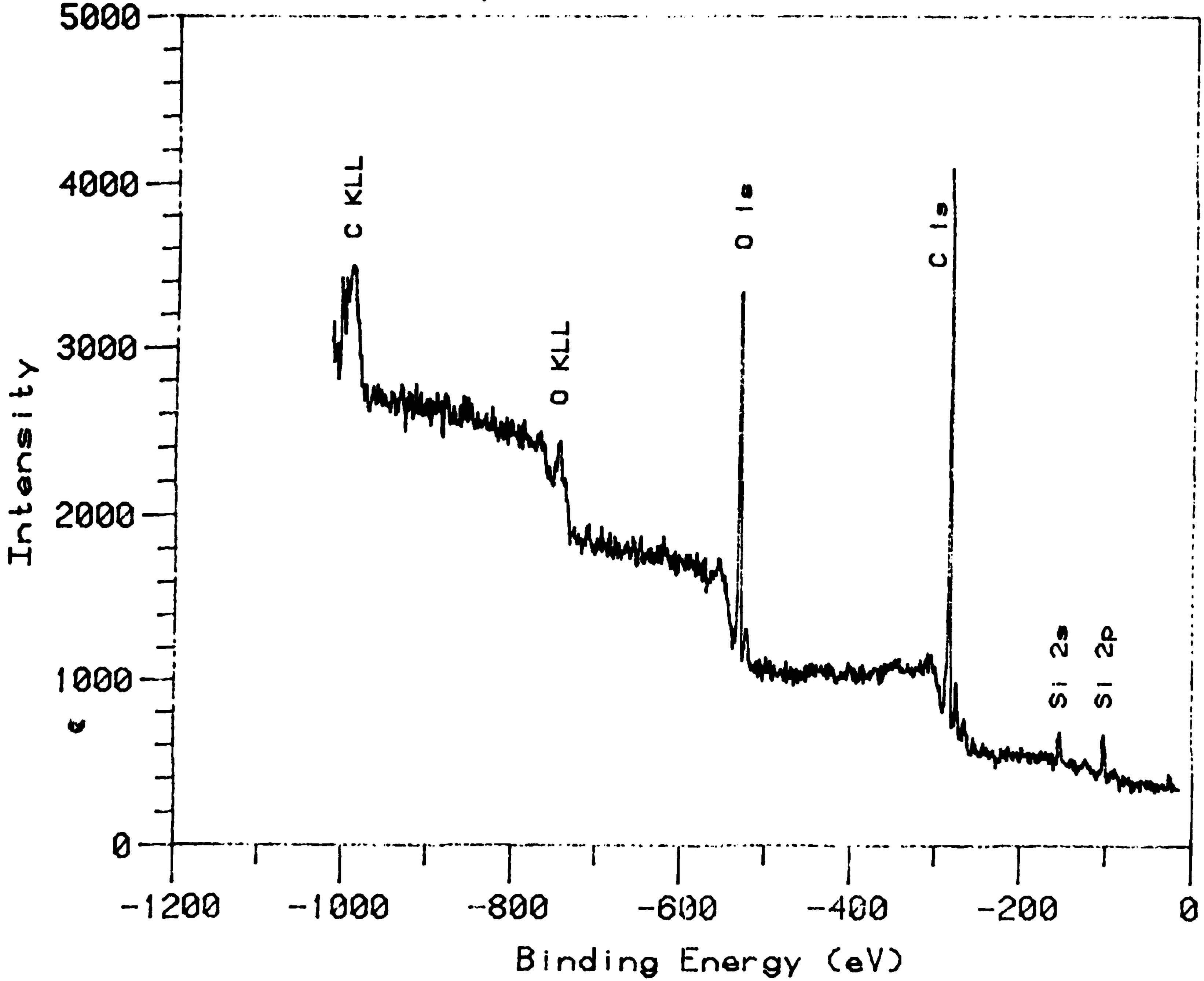
File: 102088.e08



UNIROYAL UNI-SN WT50 (Aged
O 1s Scan
6000
5000
4000
3000
2000
1000
Intensity
-545
-540
-535
-530
-525
-520
Binding Energy (eV)
PARAMETERS
Iter= 20
Dwell=0.2s
Inc=0.200eV
Operator: TW
Version: 02B
102088.e08

UNIROYAL UNI-SN W150 (Aged 1500 Hrs)

XPS Survey Scan



PARAMETERS

Iter= 10

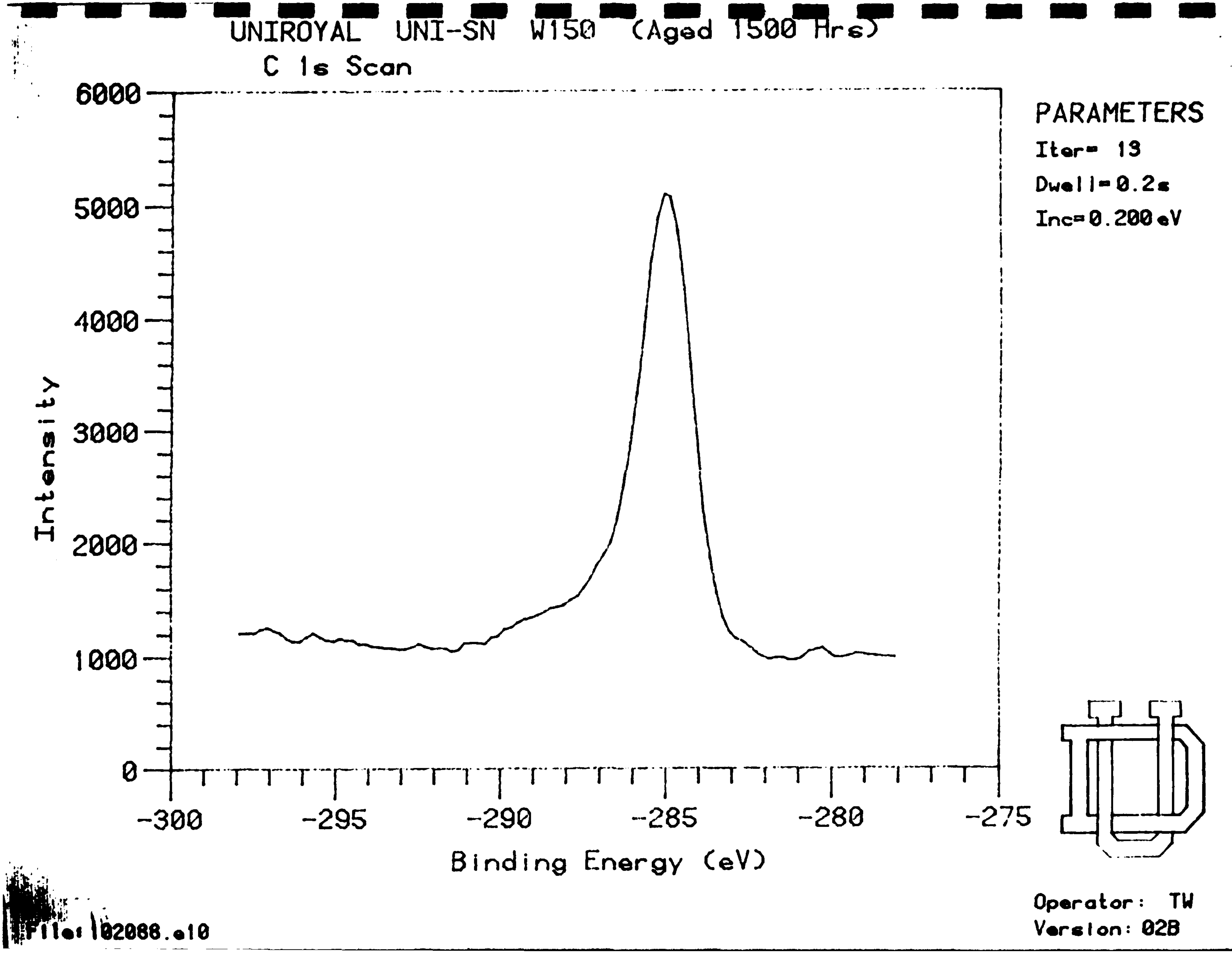
Dwell=0.1s

Inc=1.000eV

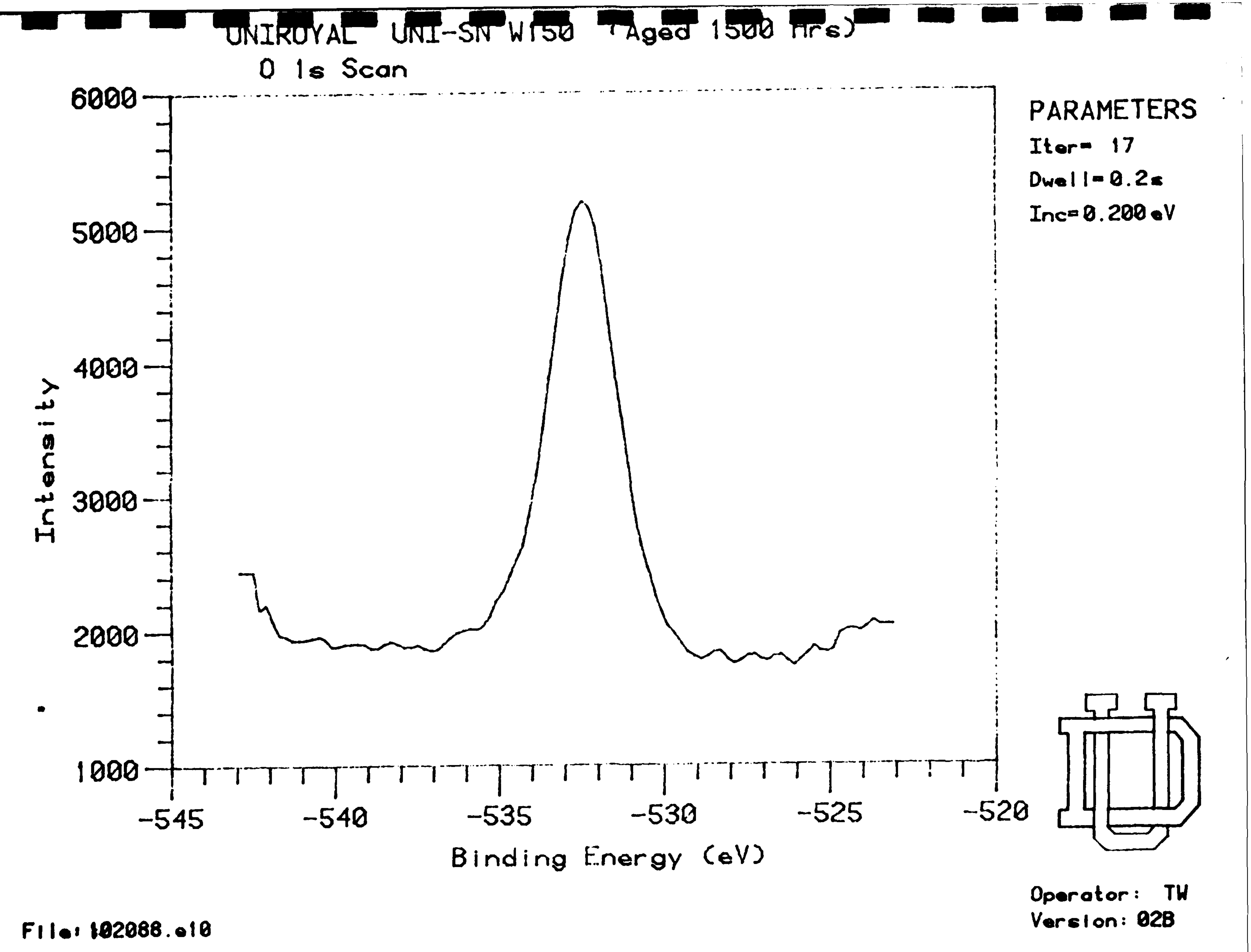
File: 102088.e09

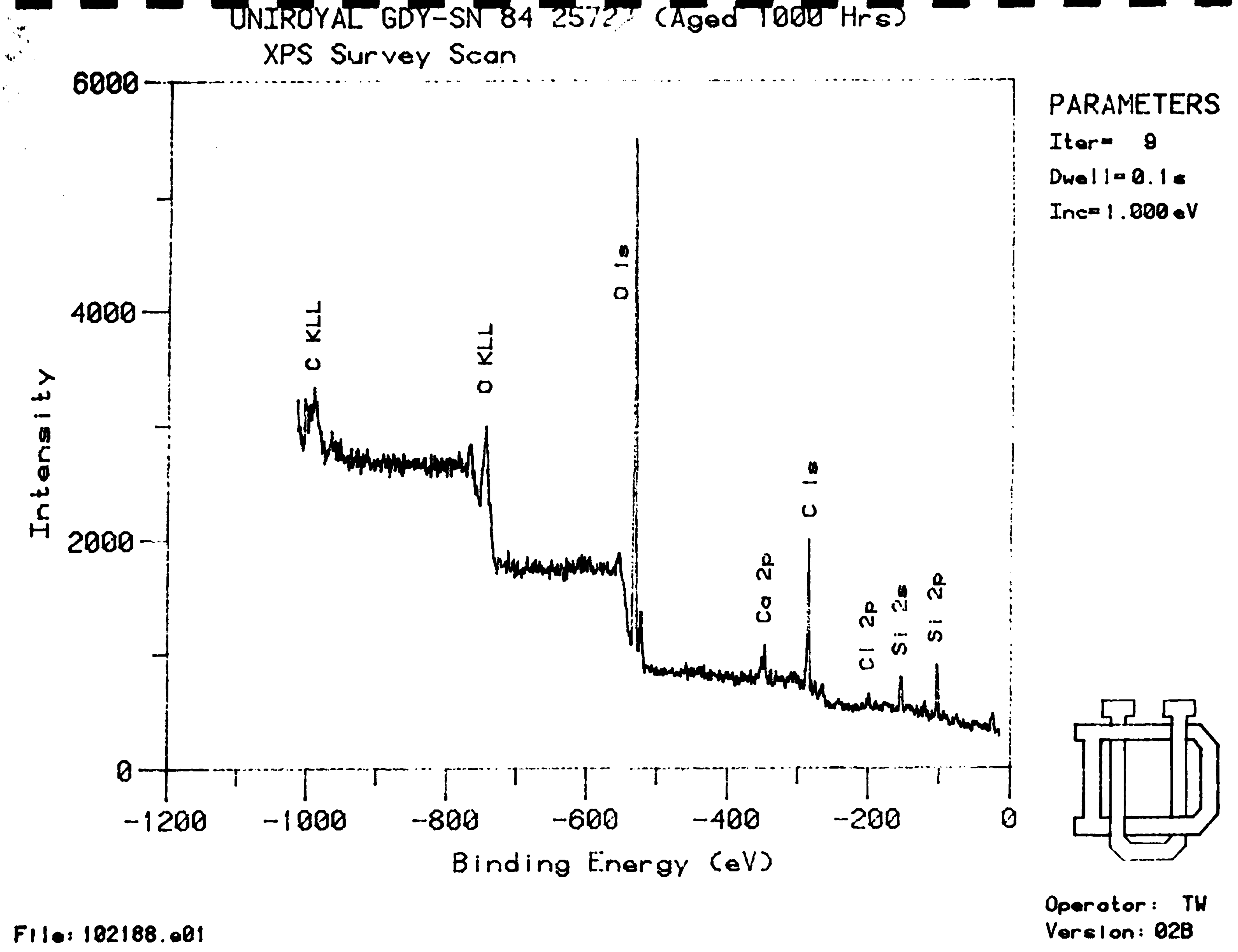
Operator: TW

Version: 02B



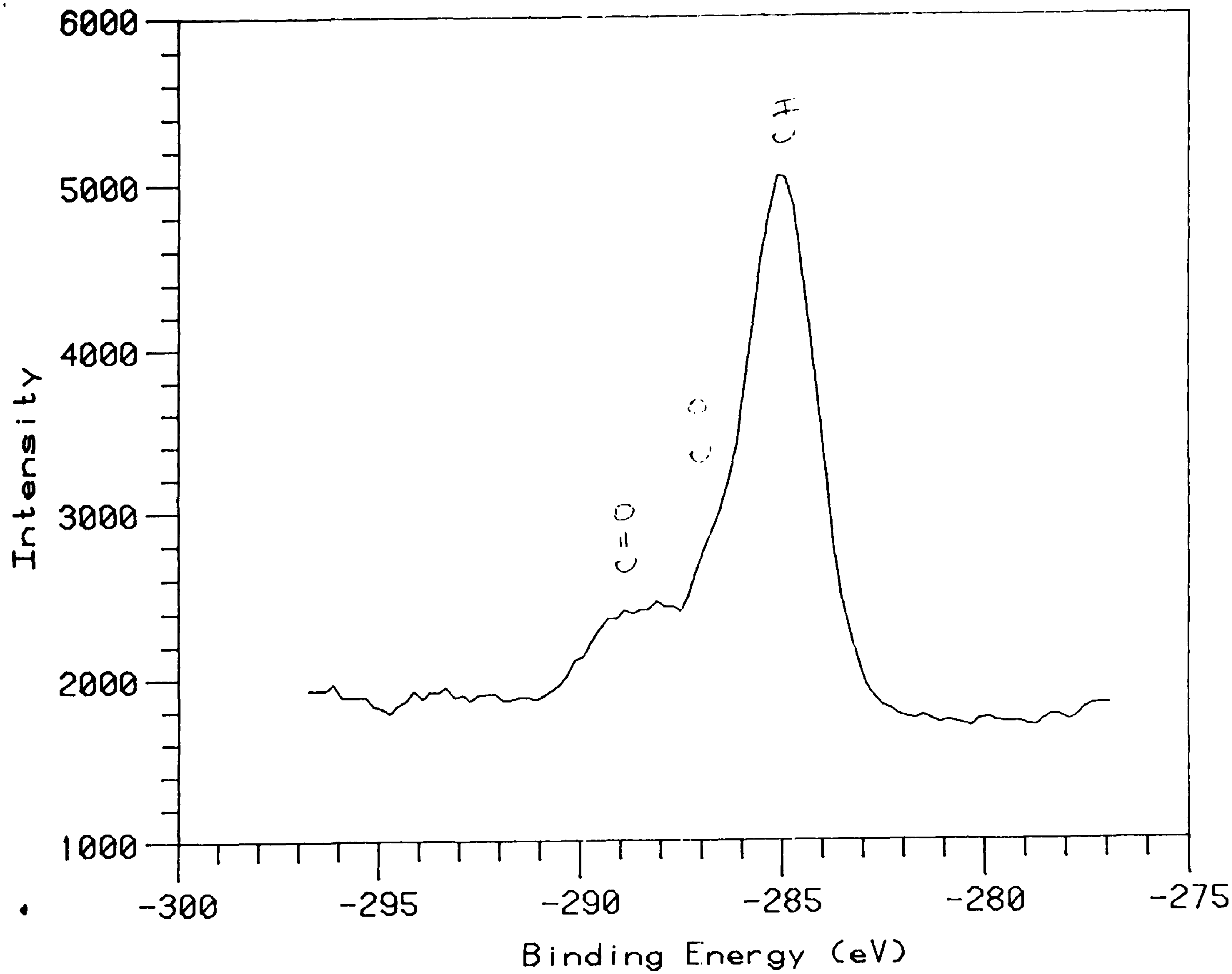
UNIROYAL UNI-SN W150 (Aged 1500 Hrs)
C 1s Scan
Intensity
6000
5000
4000
3000
2000
1000
0
-300
-295
-290
-285
-280
-275
Binding Energy (eV)
PARAMETERS
Iter= 13
Dwell=0.2s
Inc=0.200eV
Operator: TW
Version: 02B
File: 02088.e10


UNIROYAL UNI-SN W150 (Aged 1500 Hrs)
O 1s Scan
6000
5000
4000
3000
2000
1000
Intensity
-545
-540
-535
-530
-525
-520
Binding Energy (eV)
PARAMETERS
Iter= 17
Dwell=0.2s
Inc=0.200eV
Operator: TW
Version: 02B
File: 102088.e10


UNIROYAL GDY-SN 84 2572? (Aged 1000 Hrs)
XPS Survey Scan
Intensity
6000
4000
2000
0
C KLL
O KLL
O 1s
Ca 2p
C 1s
Cl 2p
Si 2s
Si 2p
-1200
-1000
-800
-600
-400
-200
0
Binding Energy (eV)
PARAMETERS
Iter= 9
Dwell=0.1s
Inc=1.000eV
Operator: TW
Version: 02B
File: 102188.e01

UNIROYAL GDY-SN 84 25727 (Aged 1000 Hrs)

C 1s Scan



PARAMETERS

Iter= 24

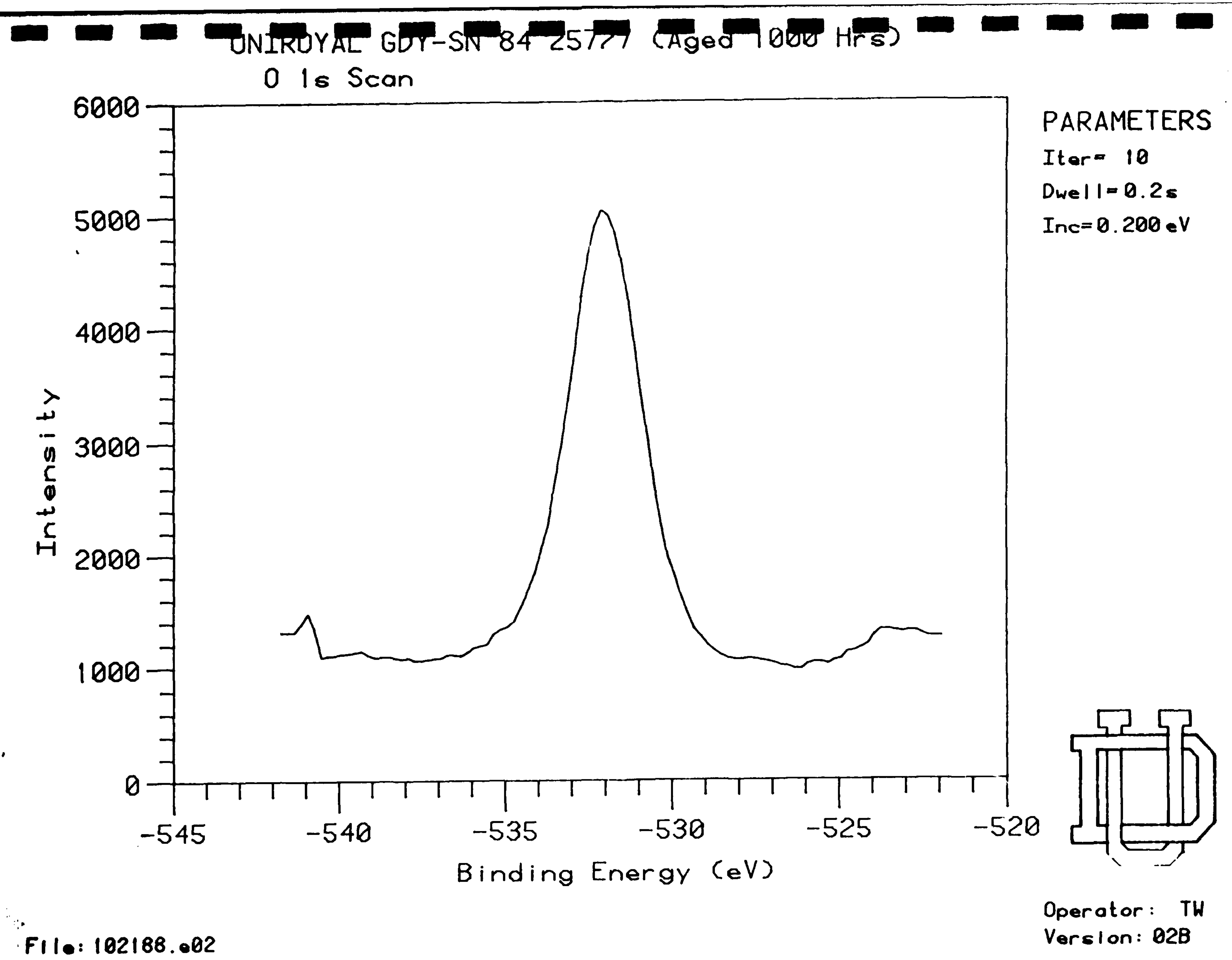
Dwell=0.2s

Inc=0.200eV

Operator: TW

Version: 02B

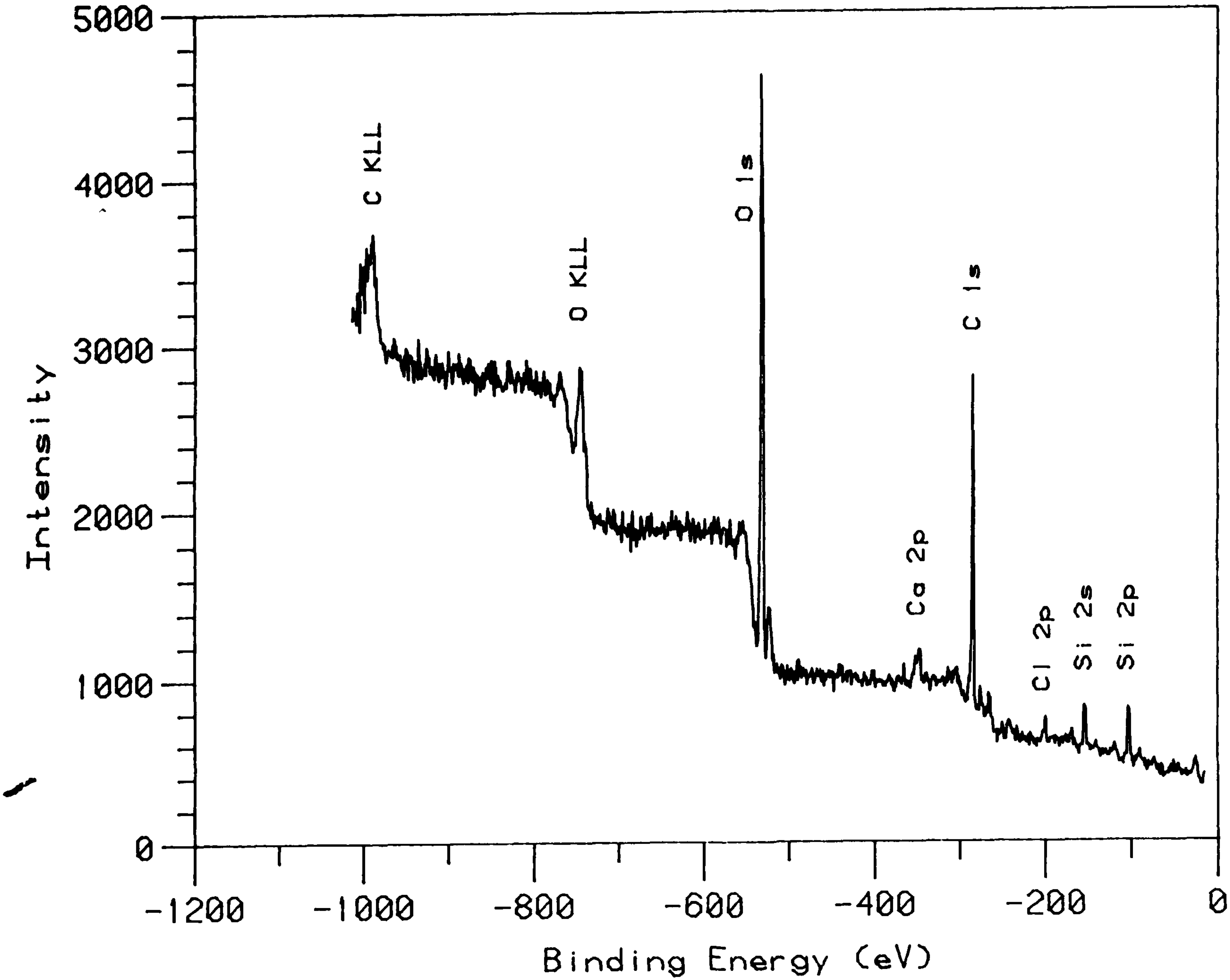
File: 102188.e02



UNIROYAL GDY-SN 84 25777 (Aged 1000 Hrs)
O 1s Scan
Intensity
6000
5000
4000
3000
2000
1000
0
-545
-540
-535
-530
-525
-520
Binding Energy (eV)
PARAMETERS
Iter= 10
Dwell=0.2s
Inc=0.200eV
Operator: TW
Version: 02B
File: 102188.e02

UNIROYAL GDT-SN 84-25727 (AGED 1500 HRS)

XPS Survey Scan



PARAMETERS

Iter= 11

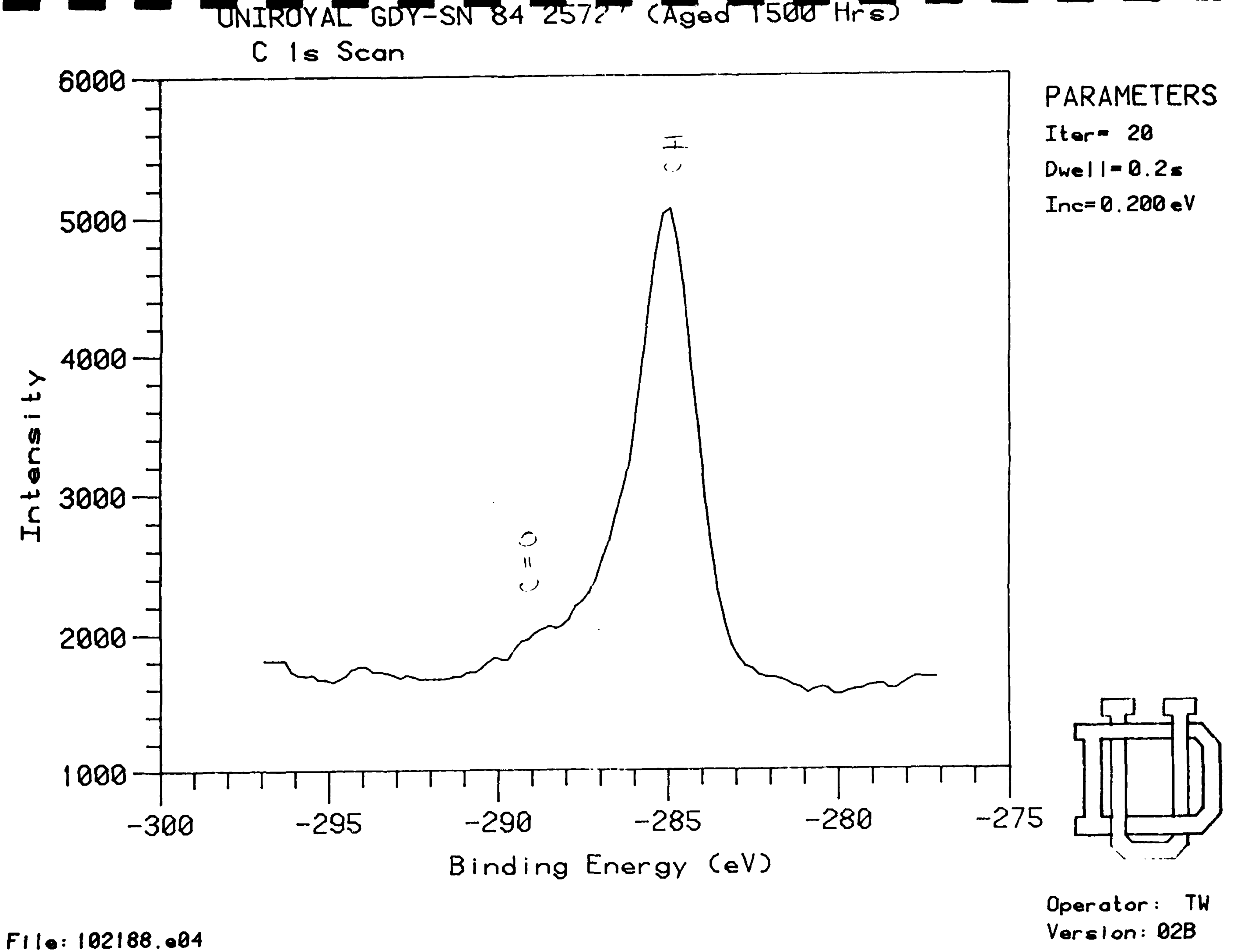
Dwell=0.1s

Inc=1.000eV

Operator: TW

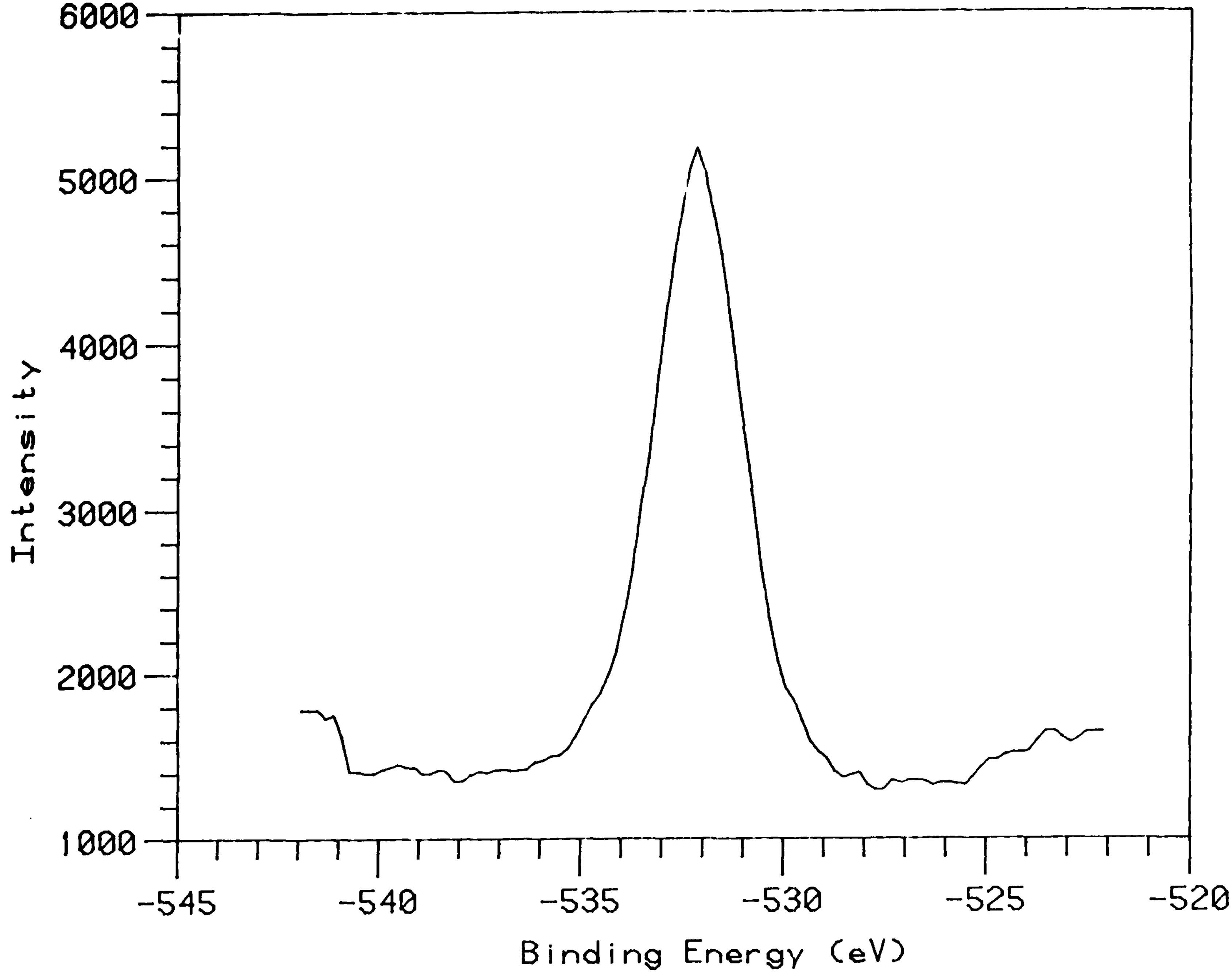
Version: 02B

File: 102188.E03


UNIROYAL GDY-SN 84 2572" (Aged 1500 Hrs)
C 1s Scan
PARAMETERS
Iter= 20
Dwell=0.2s
Inc=0.200eV
C-H
C=O
6000
5000
4000
3000
2000
1000
Intensity
-300
-295
-290
-285
-280
-275
Binding Energy (eV)
Operator: TW
Version: 02B
File: 102188.e04

UNIROYAL GDY-SN 84 25727 (Aged 1500 Hrs)

O 1s Scan



PARAMETERS

Iter= 13

Dwell=0.2s

Inc=0.200eV

Operator: TW

Version: 02B

File: 102188.e04

The University of Dayton

20 July 1988

Mr. P. A. Lightner
Uniroyal Plastics Company Inc.
312 North Hill Street
P.O. Box 2000
Mishawaka, IN 46544-1399

Dear Mr. Lightner:

I have used XPS to analyze the eight storage tank elastomer samples that I received from you last week. The following table gives the measured carbon/oxygen atom % ratios for the surfaces of interest.

Sample	%Carbon/%Oxygen
GDY-S/N 84-13805	4.2
UNI-S/N W-240	3.4
ILC-S/N 794	2.5
UNI-S/N W-158	4.2
UNI-S/N W-155	3.9
UNI-S/N W-358	3.9
GDY-S/N 84-25727 (500 hr. W.O.)	1.8
UNI-S/N W-150 (500 hr. W.O.)	3.1

I have included copies of the carbon 1s and oxygen 1s photoelectron peaks for each sample. I have also included a survey scan for each sample which, in some cases, shows that other elements such as chlorine, silicon, zinc and nitrogen are also detected.

RESEARCH INSTITUTE
300 College Park Dayton, Ohio 45469-0001

I noticed that the two 500 hr. samples were taped to the white paper. I should caution you against marking or putting tape anywhere on the surface of interest since even an area away from this can be contaminated via surface diffusion. You should also, of course, avoid touching the surface of interest since skin oil and salt can be transferred to the sample.

Please let me know if you have any questions about the data.

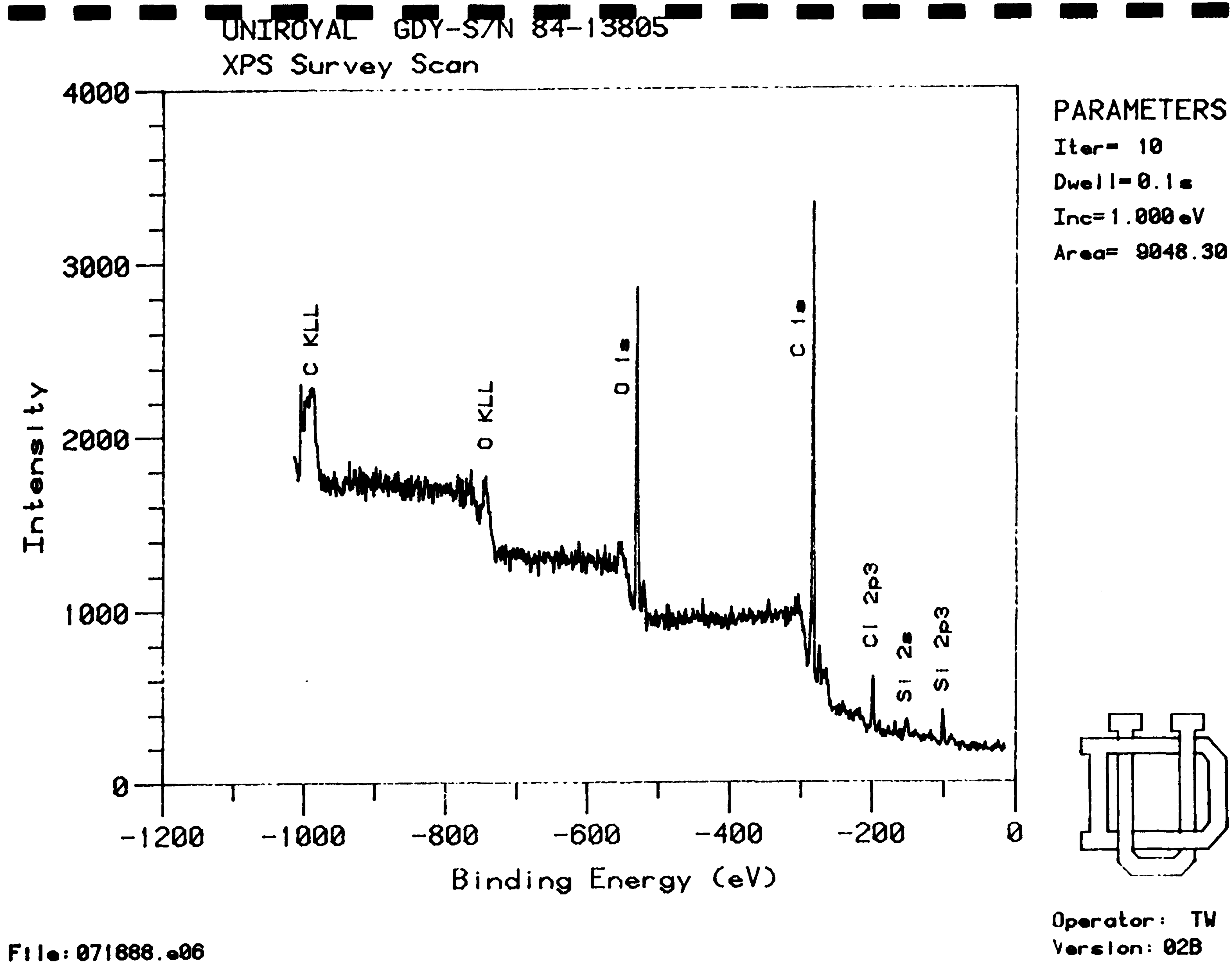
Sincerely,

Tom Wittberg

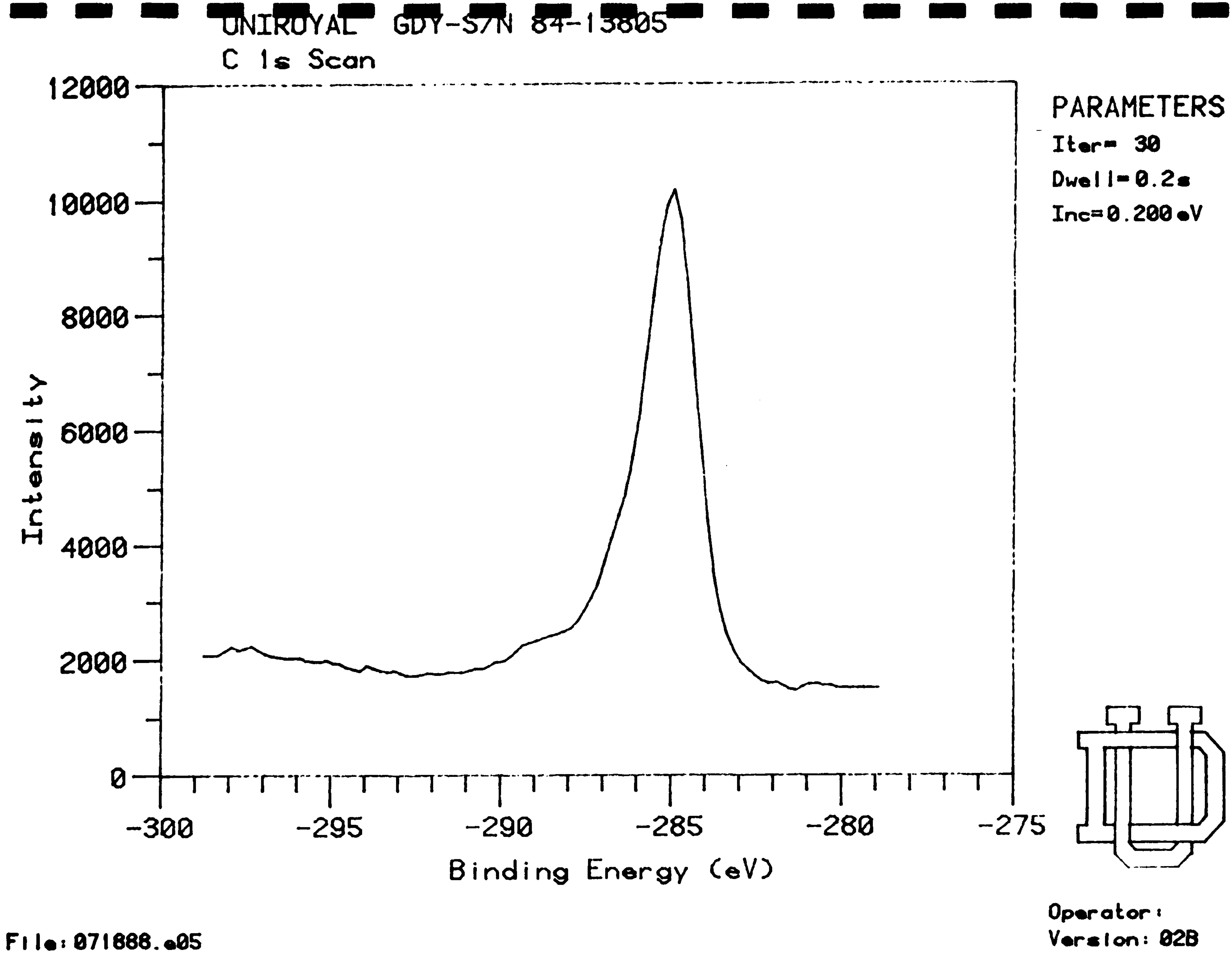
Tom Wittberg

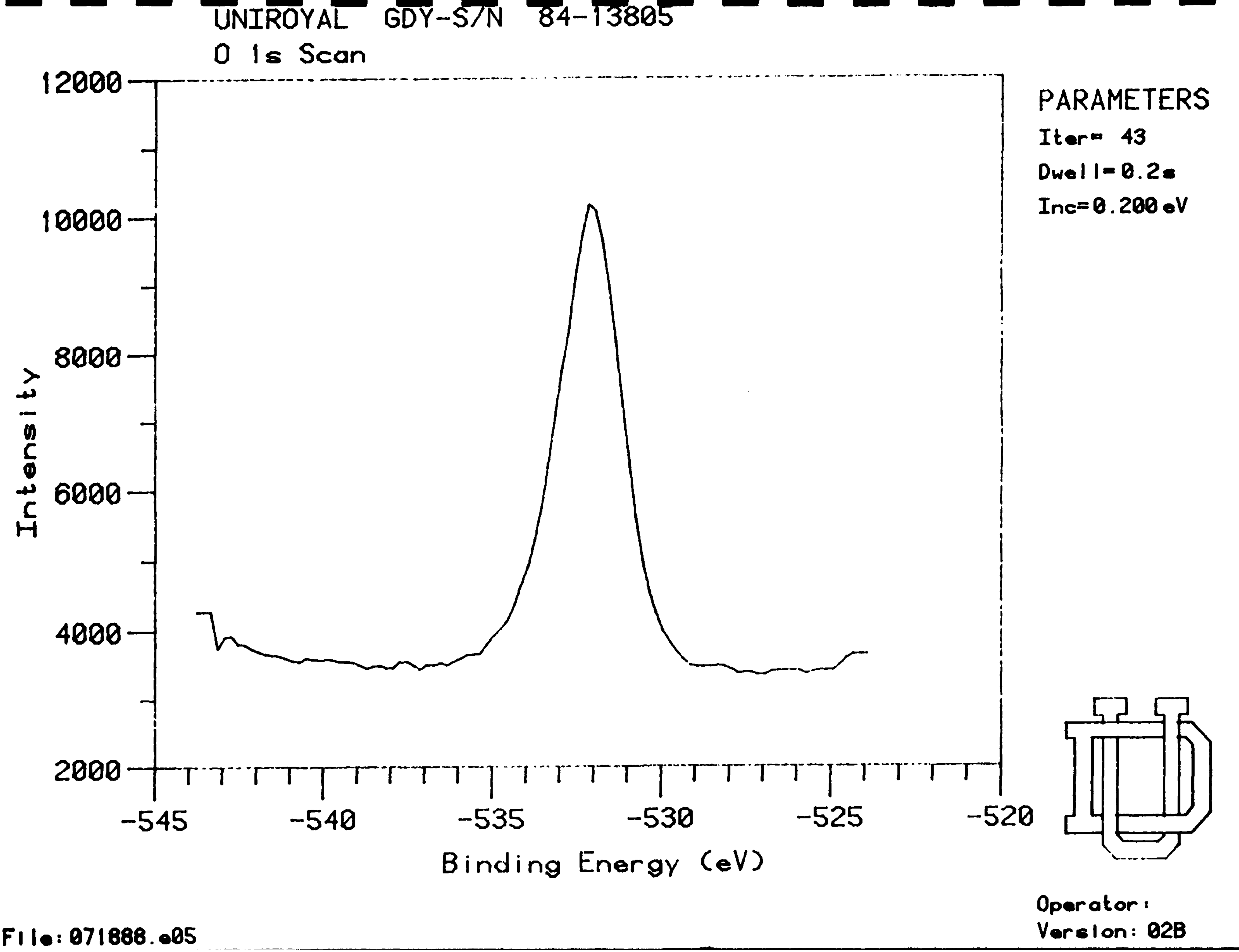
TW:prc

Enclosures



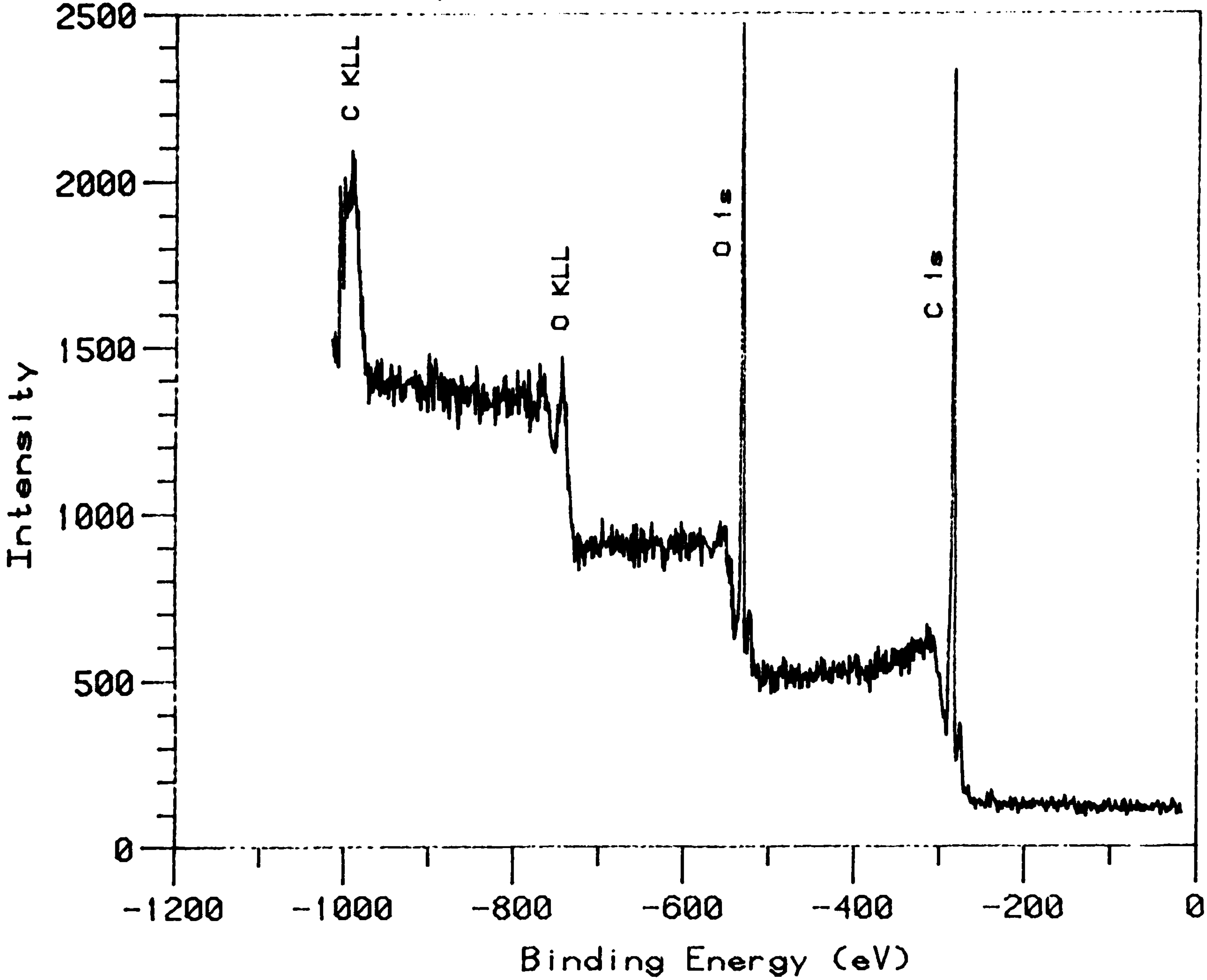
UNIROYAL GDY-S/N 84-13805
XPS Survey Scan
Intensity
4000
3000
2000
1000
0
-1200
-1000
-800
-600
-400
-200
0
Binding Energy (eV)
C KLL
O KLL
O 1s
C 1s
Cl 2p3
Si 2s
Si 2p3
PARAMETERS
Iter= 10
Dwell=0.1s
Inc=1.000eV
Area= 9048.30
Operator: TW
Version: 02B
File: 071888.e06


UNIROYAL GDY-S/N 84-13805
C 1s Scan
12000
10000
8000
6000
4000
2000
0
Intensity
-300
-295
-290
-285
-280
-275
Binding Energy (eV)
PARAMETERS
Iter= 30
Dwell=0.2s
Inc=0.200eV
Operator:
Version: 02B
File: 071888.e05


UNIROYAL GDY-S/N 84-13805
O 1s Scan
12000
10000
8000
6000
4000
2000
Intensity
-545
-540
-535
-530
-525
-520
Binding Energy (eV)
PARAMETERS
Iter= 43
Dwell=0.2s
Inc=0.200 eV
Operator:
Version: 02B
File: 071888.e05

UNIROYAL UNI-S7N W-240

XPS Survey Scan



PARAMETERS

Iter= 10

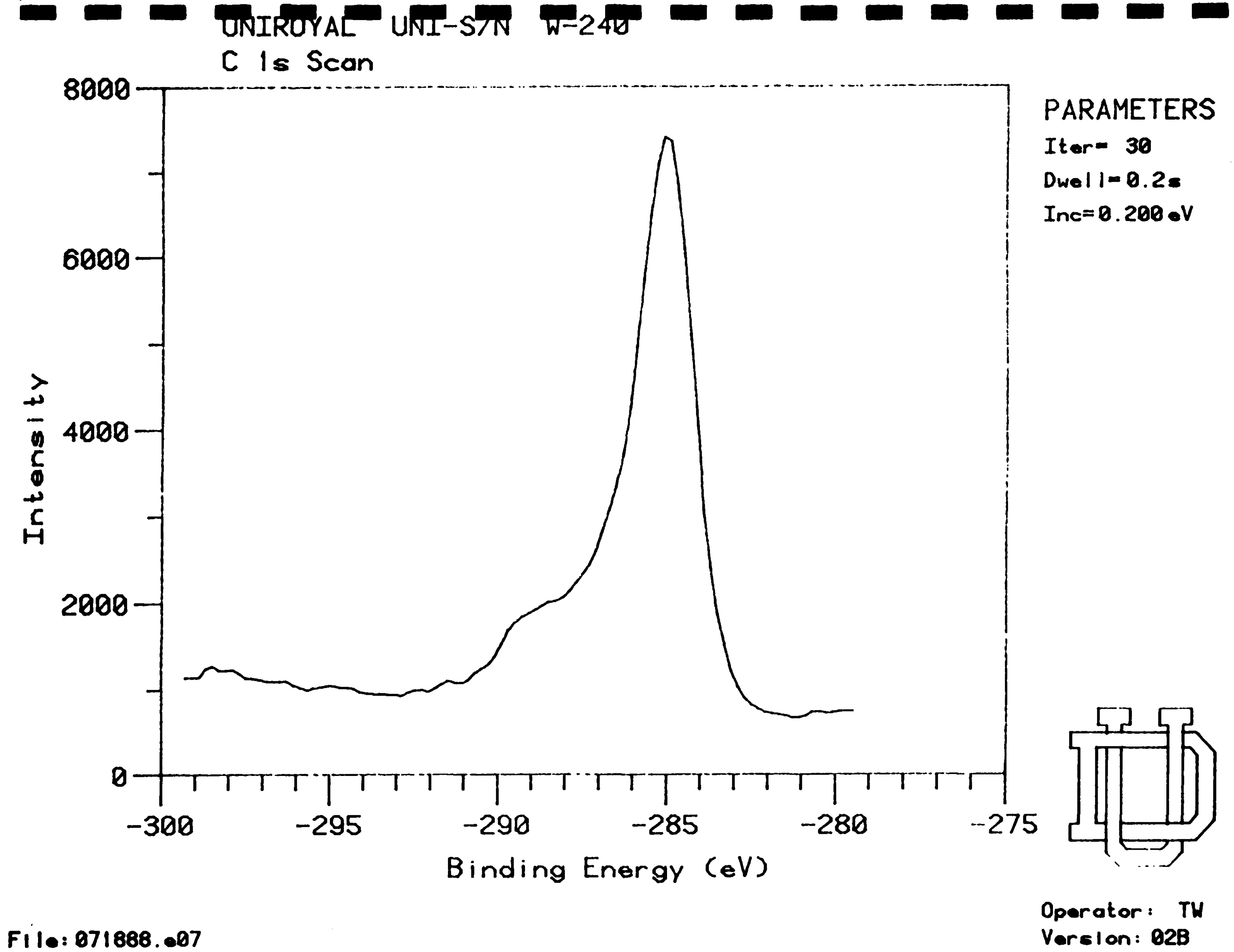
Dwell=0.1s

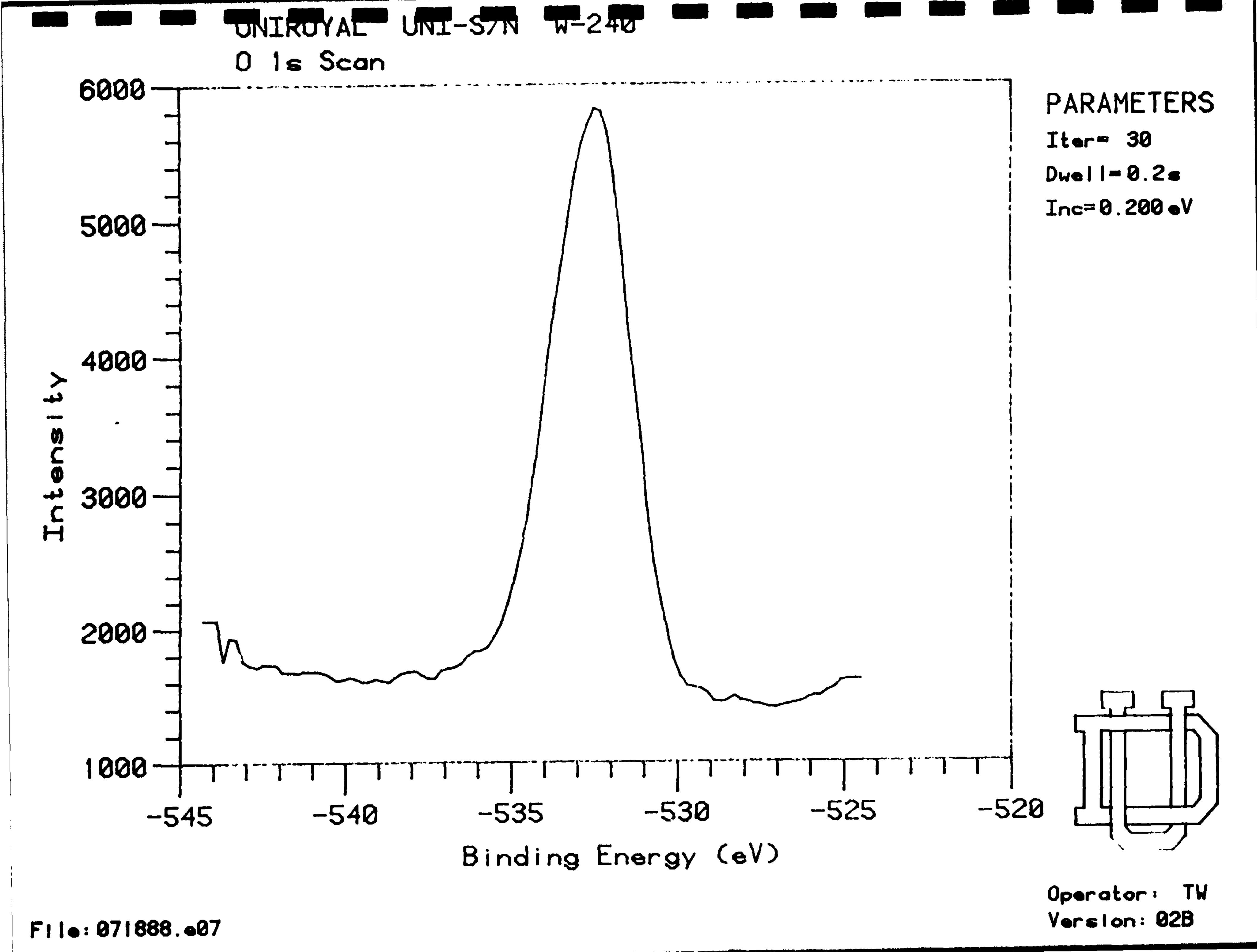
Inc=1.000eV

Operator: TW

Version: 02B

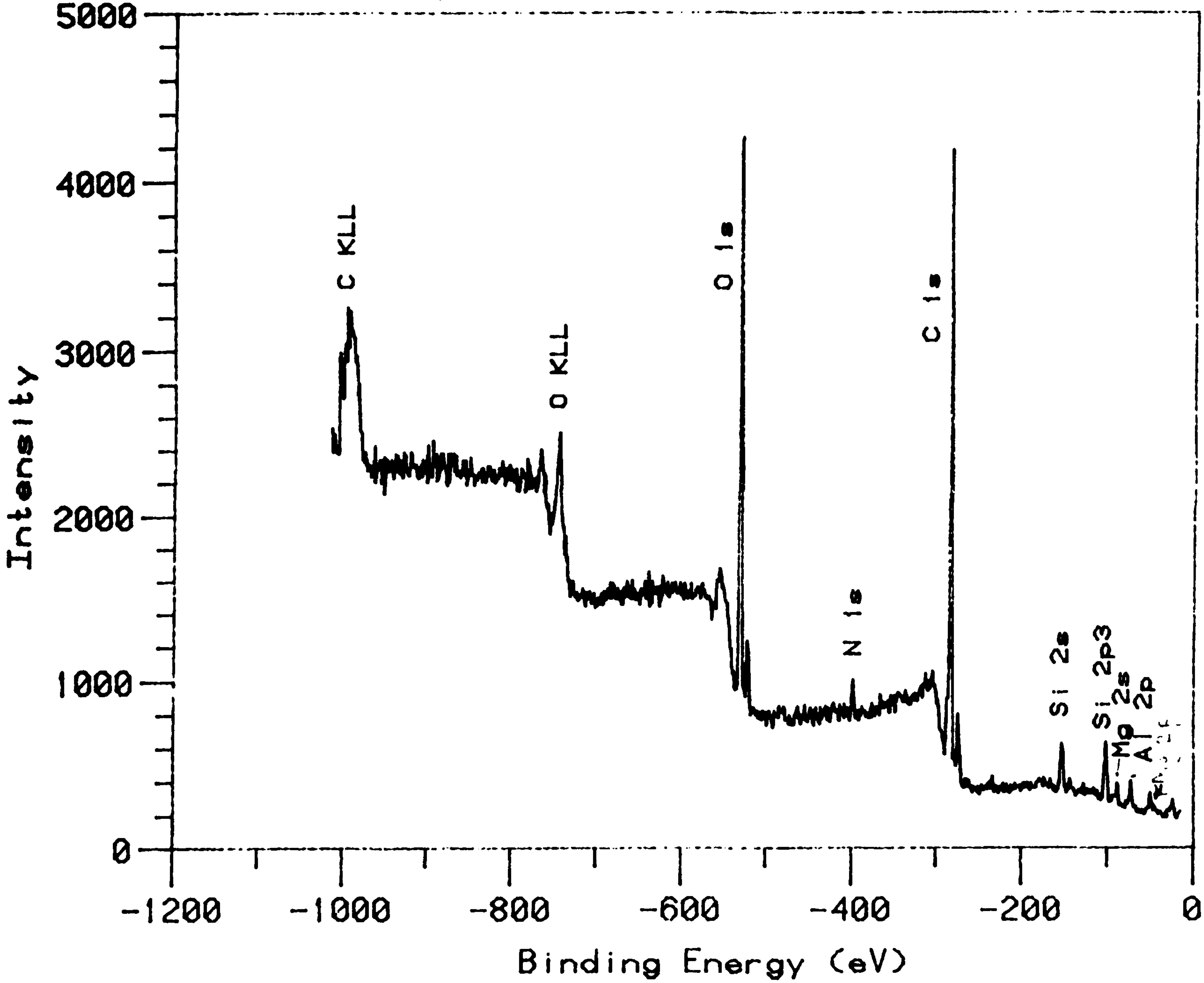
File: 071888.e08


UNIROYAL UNI-S7N W-240
C 1s Scan
8000
6000
4000
2000
0
Intensity
-300
-295
-290
-285
-280
-275
Binding Energy (eV)
PARAMETERS
Iter= 30
Dwell=0.2s
Inc=0.200eV
Operator: TW
Version: 02B
File: 071888.e07


UNIROYAL UNI-S/N W-240
O 1s Scan
6000
5000
4000
3000
2000
1000
Intensity
-545
-540
-535
-530
-525
-520
Binding Energy (eV)
PARAMETERS
Iter= 30
Dwell=0.2s
Inc=0.200eV
Operator: TW
Version: 02B
File: 071888.e07

UNIROYAL ILC S/N 794

XPS Survey Scan

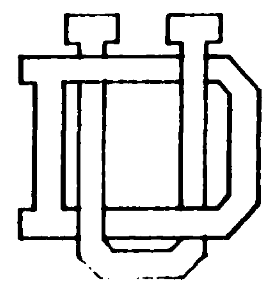


PARAMETERS

Iter= 10

Dwell=0.1s

Inc=1.000eV

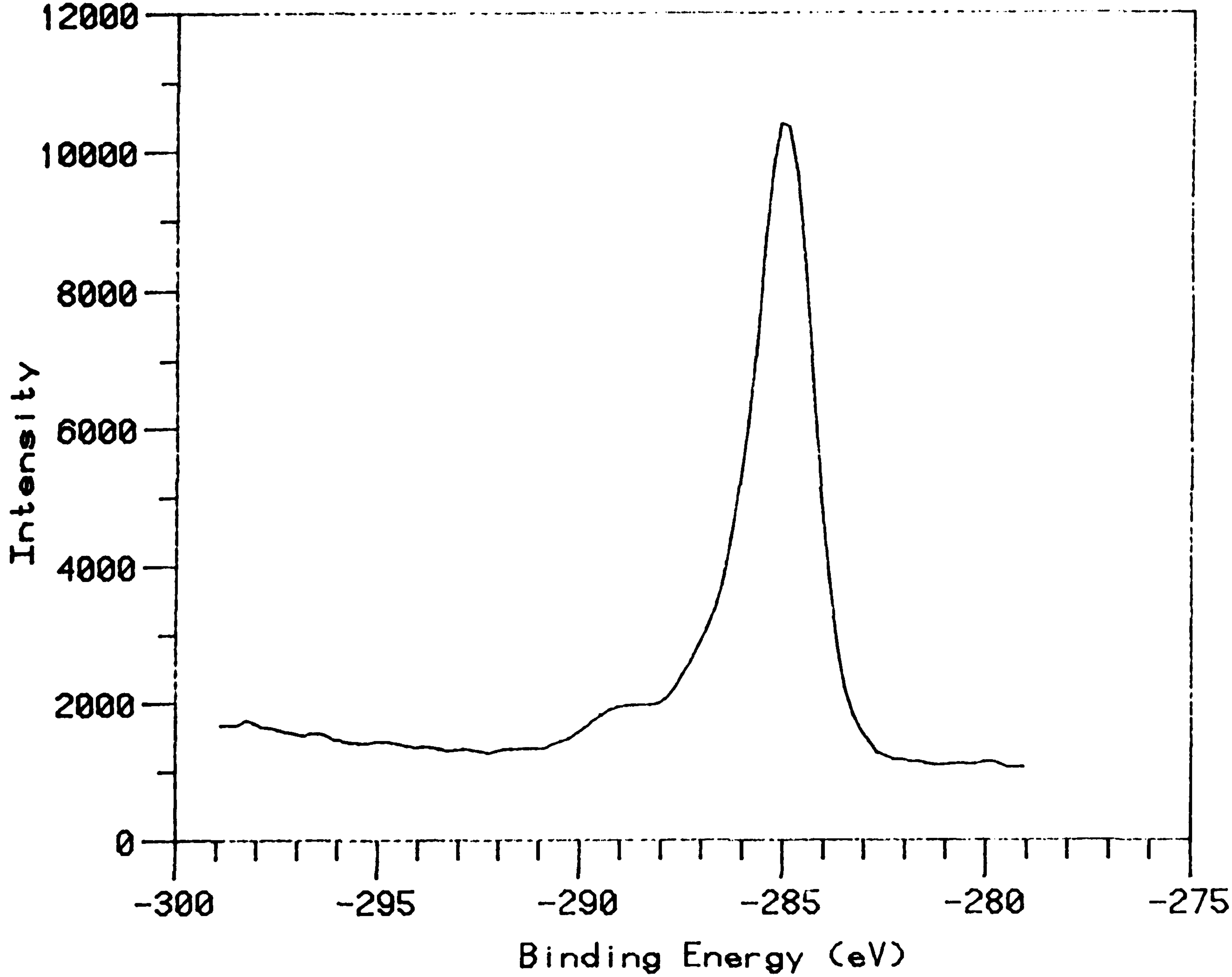


Operator: TW

Version: 02B

File: 071888.e10

UNIROYAL ILC-S/N 794
C 1s Scan



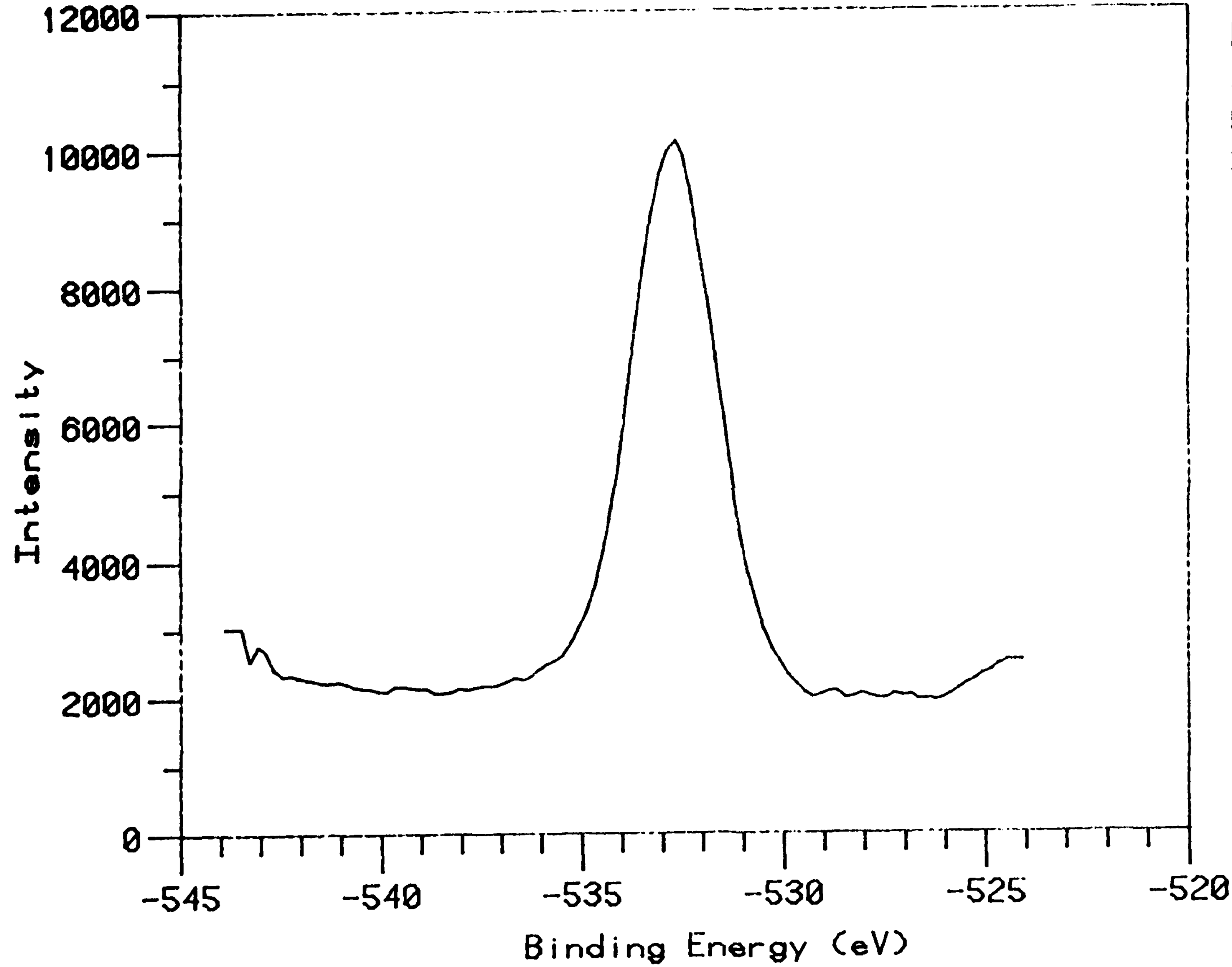
PARAMETERS
Iter= 25
Dwell=0.2s
Inc=0.200eV

Operator: TW
Version: 02B

File: 071888.e09

UNIROYAL ILC-S/N 794

O 1s Scan



PARAMETERS

Iter= 27

Dwell=0.2s

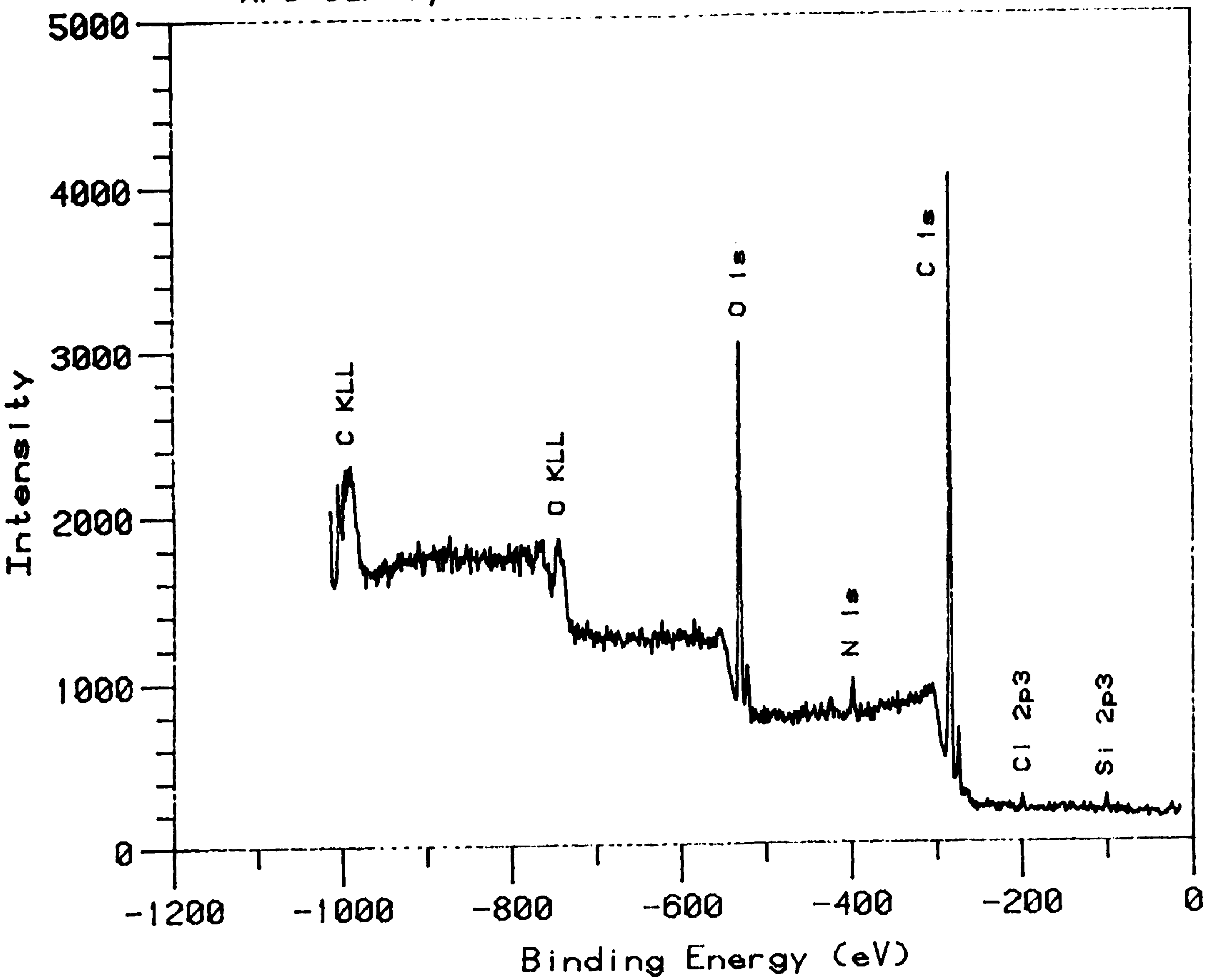
Inc=0.200eV

Operator: TW

Version: 02B

File: 071888.e09

UNIROYAL S/N-W-158
XPS Survey Scan



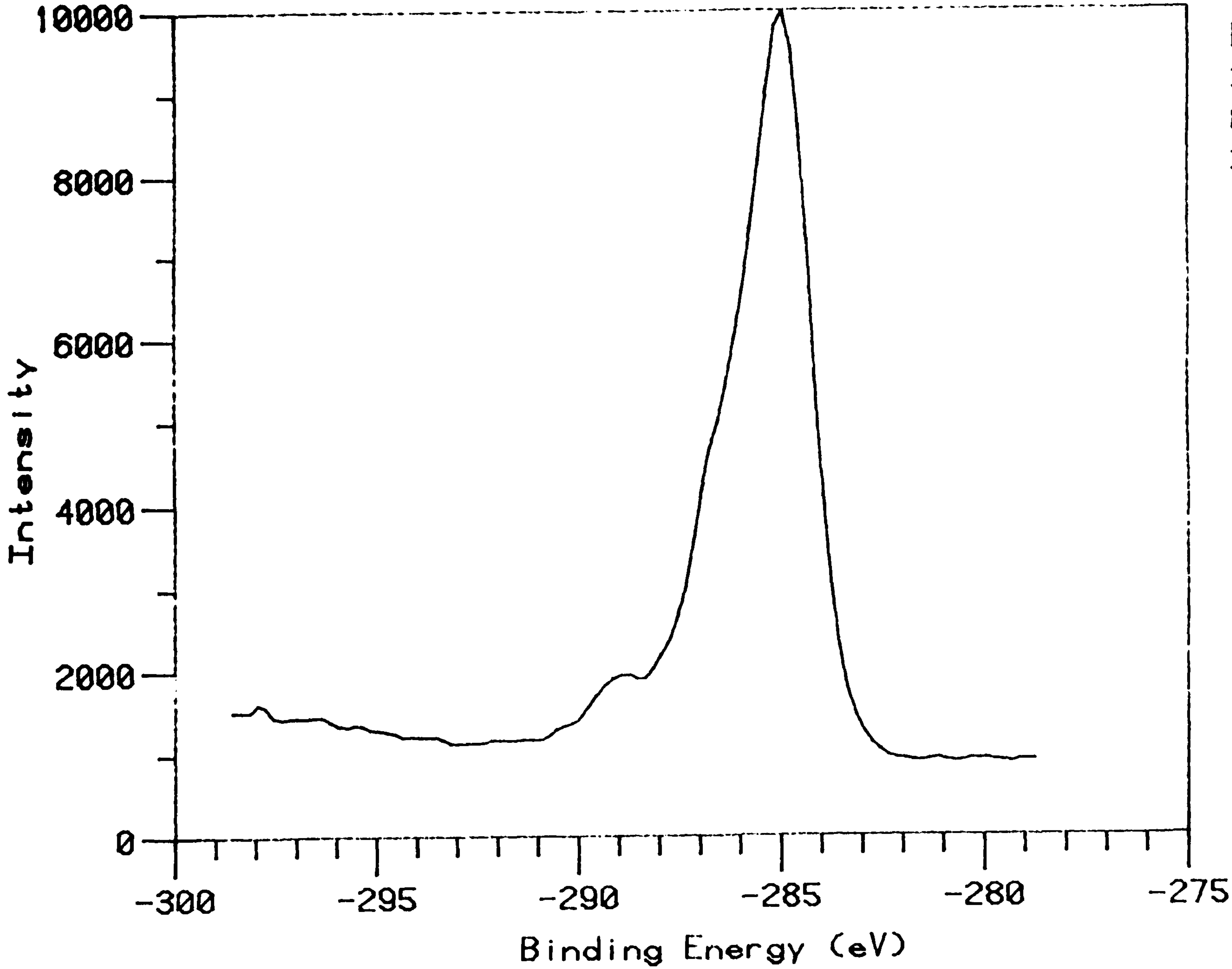
PARAMETERS
Iter= 11
Dwell=0.1s
Inc=1.000eV

Operator: TW
Version: 02B

File: 071888.e02

UNIROYAL S/N-W-158

C 1s Scan



PARAMETERS

Iter= 29

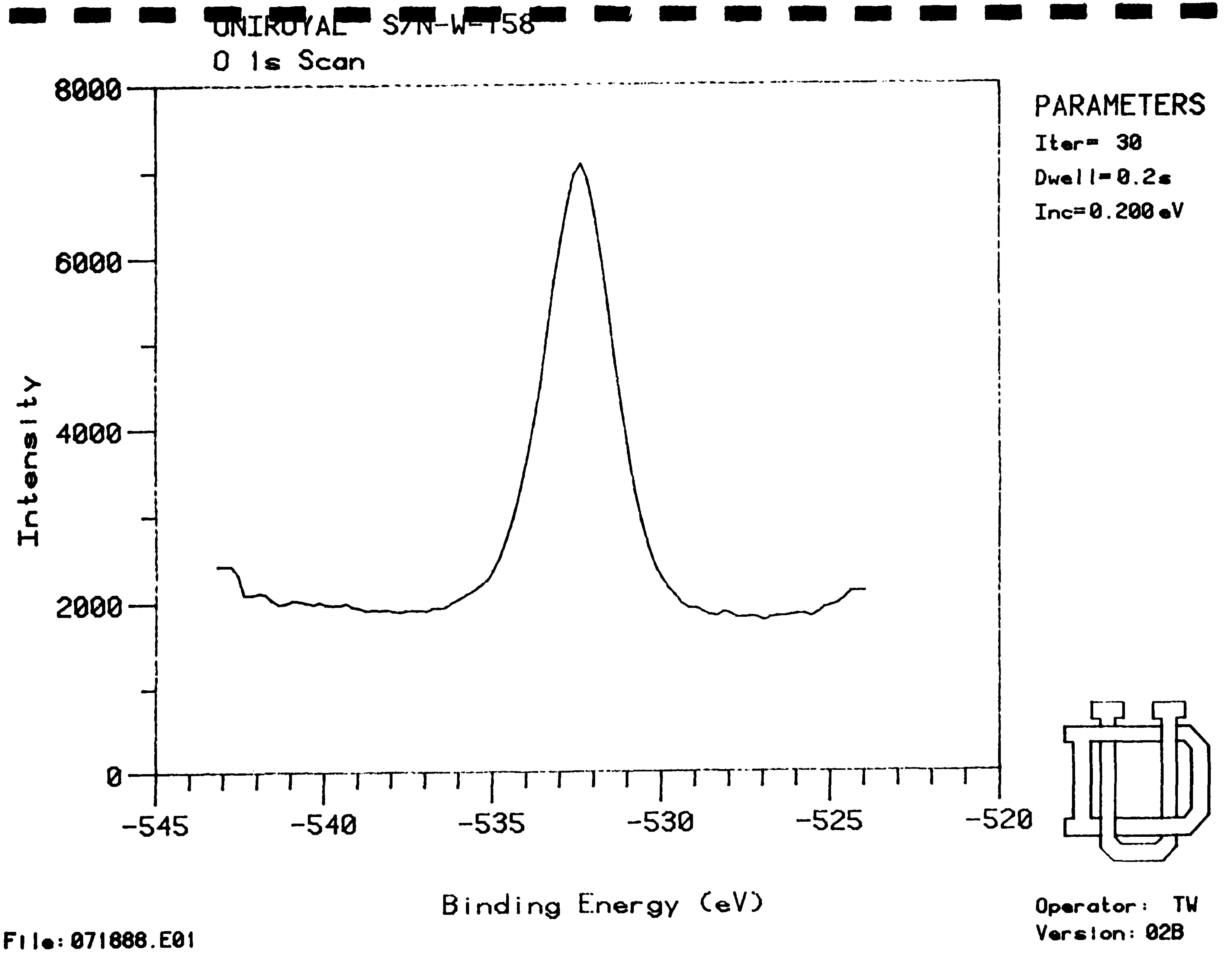
Dwell=0.2s

Inc=0.200eV

Operator: TW

Version: 02B

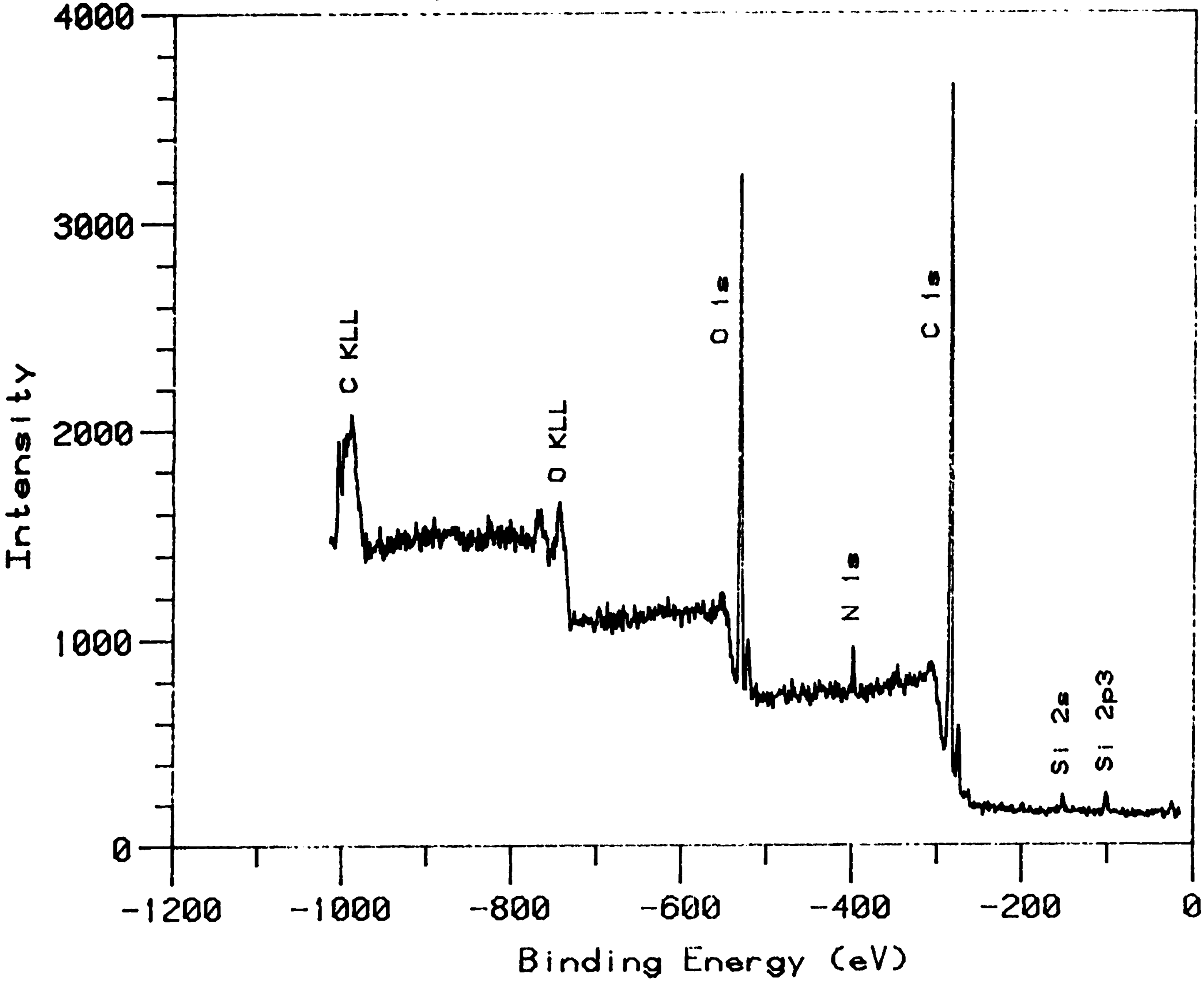
File: 071888.E01



UNIROYAL S/N-W-T58
O 1s Scan
8000
6000
4000
2000
0
Intensity
-545
-540
-535
-530
-525
-520
Binding Energy (eV)
PARAMETERS
Iter= 30
Dwell=0.2s
Inc=0.200eV
Operator: TW
Version: 02B
File: 071888.E01

UNIROYAL UNI-S/N-W-155

XPS Survey Scan

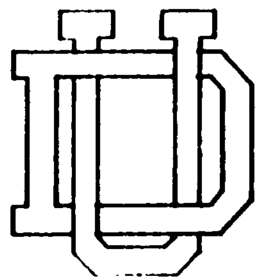


PARAMETERS

Iter= 10

Dwell=0.1s

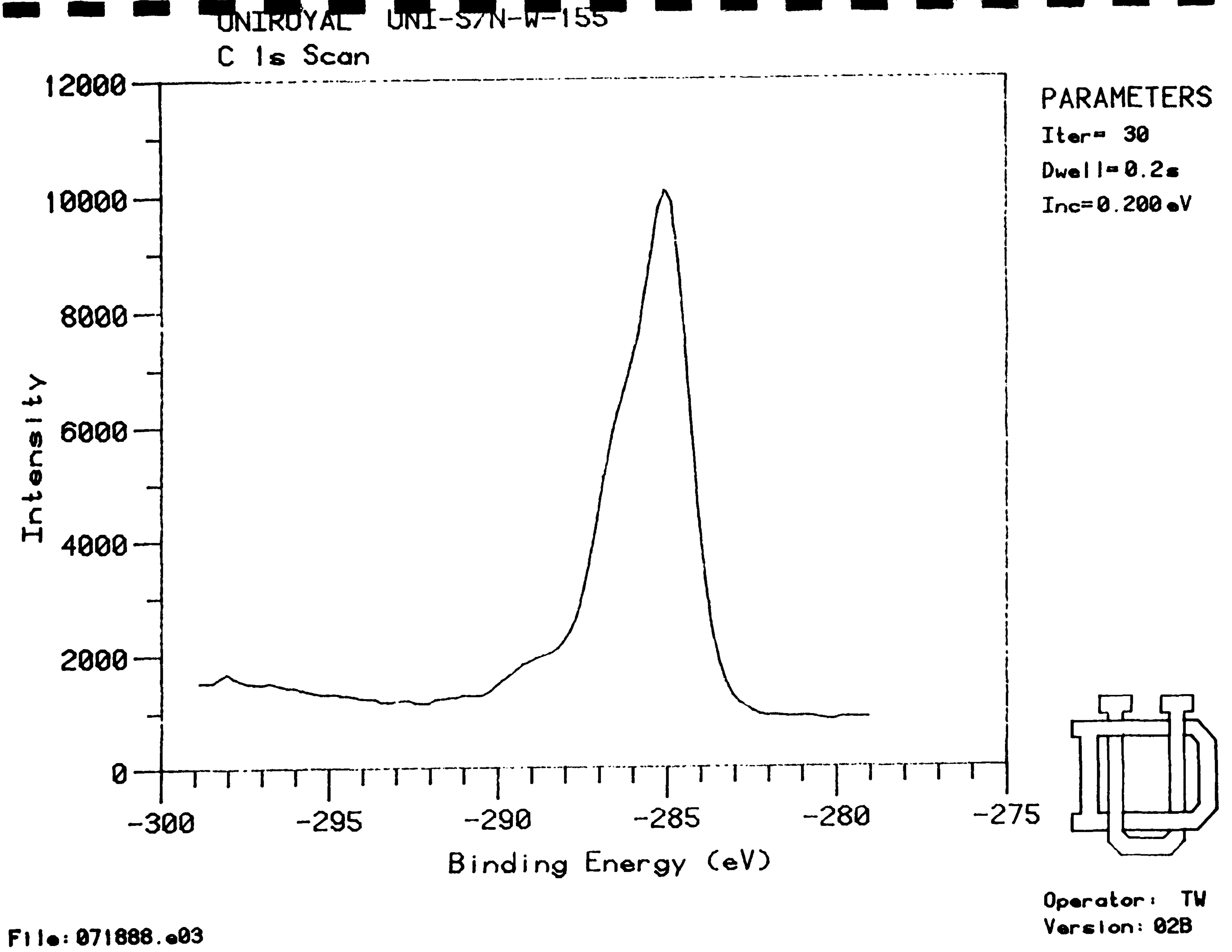
Inc=1.000eV

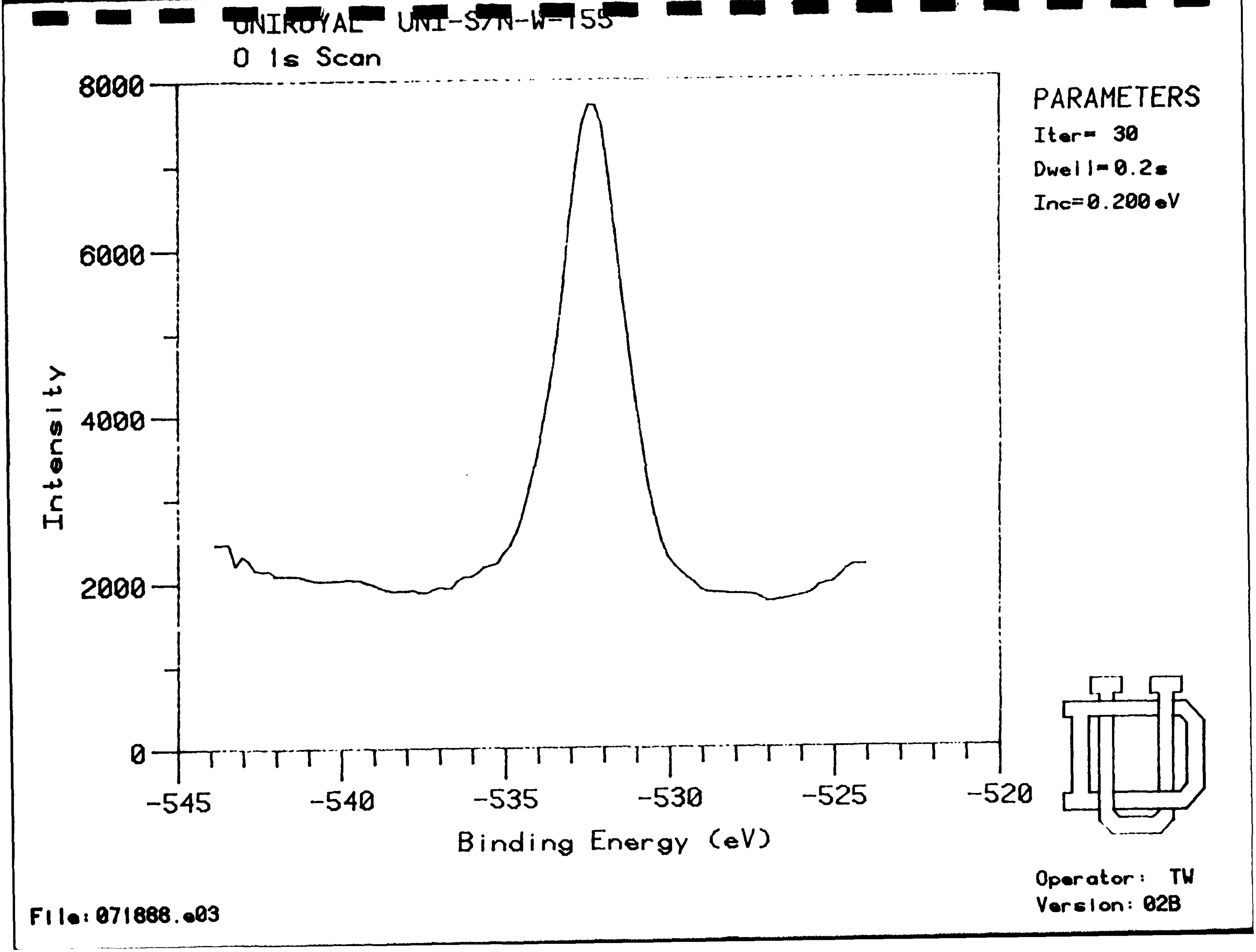


Operator: TW

Version: 02B

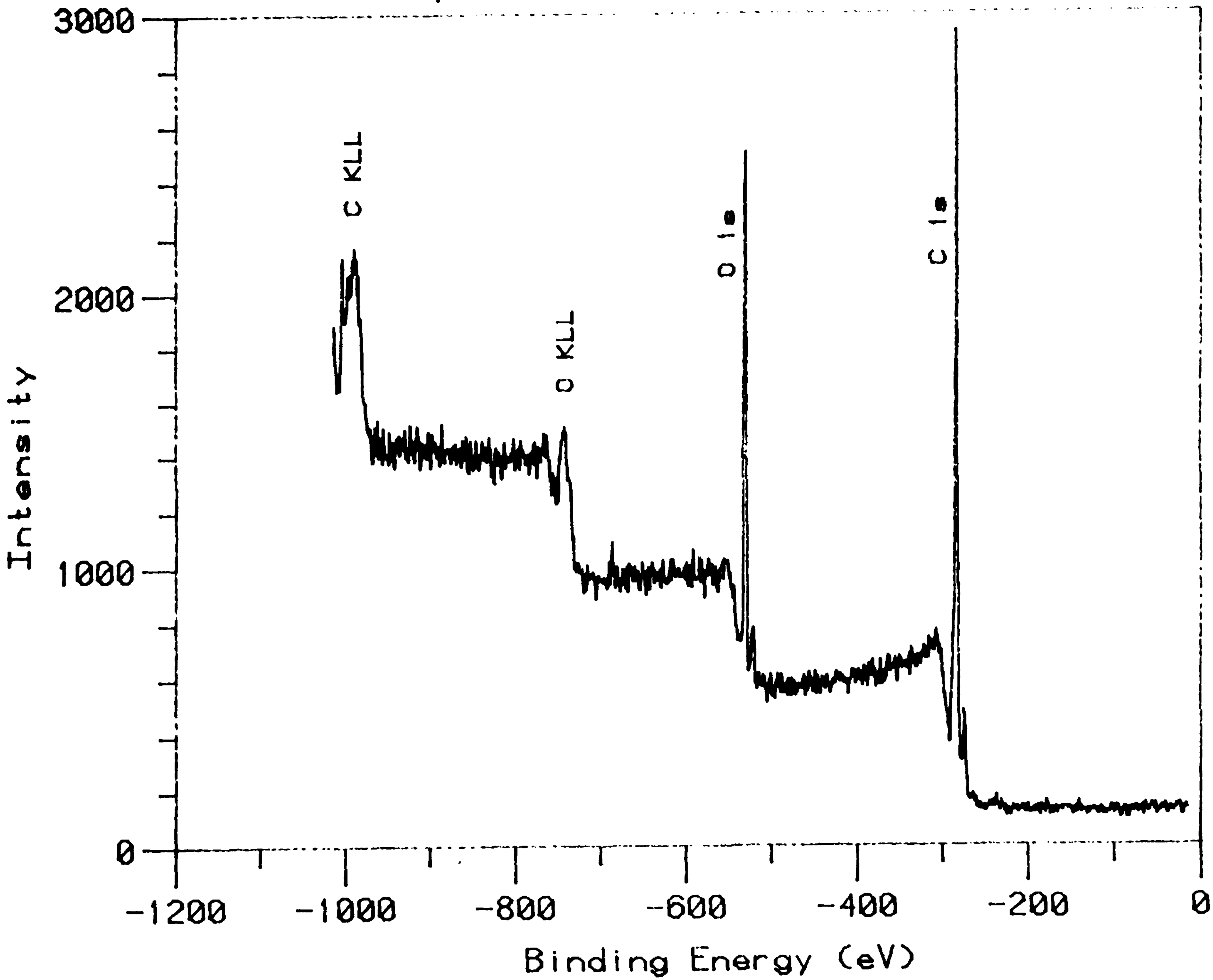
File: 071888.e04


UNIROYAL UNI-S7N-W-155
C 1s Scan
PARAMETERS
Iter= 30
Dwell=0.2s
Inc=0.200eV
Intensity
0
2000
4000
6000
8000
10000
12000
-300
-295
-290
-285
-280
-275
Binding Energy (eV)
Operator: TW
Version: 02B
File: 071888.e03


UNIROYAL UNI-S/N-W-155
O 1s Scan
PARAMETERS
Iter= 30
Dwell=0.2s
Inc=0.200eV
Intensity
8000
6000
4000
2000
0
-545
-540
-535
-530
-525
-520
Binding Energy (eV)
Operator: TW
Version: 02B
File:071888.e03

UNIROYAL UNI-S/N W-358

XPS Survey Scan

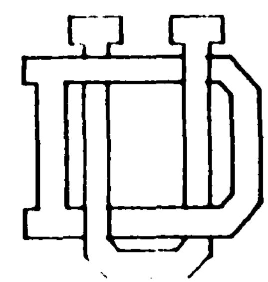


PARAMETERS

Iter= 10

Dwell=0.1s

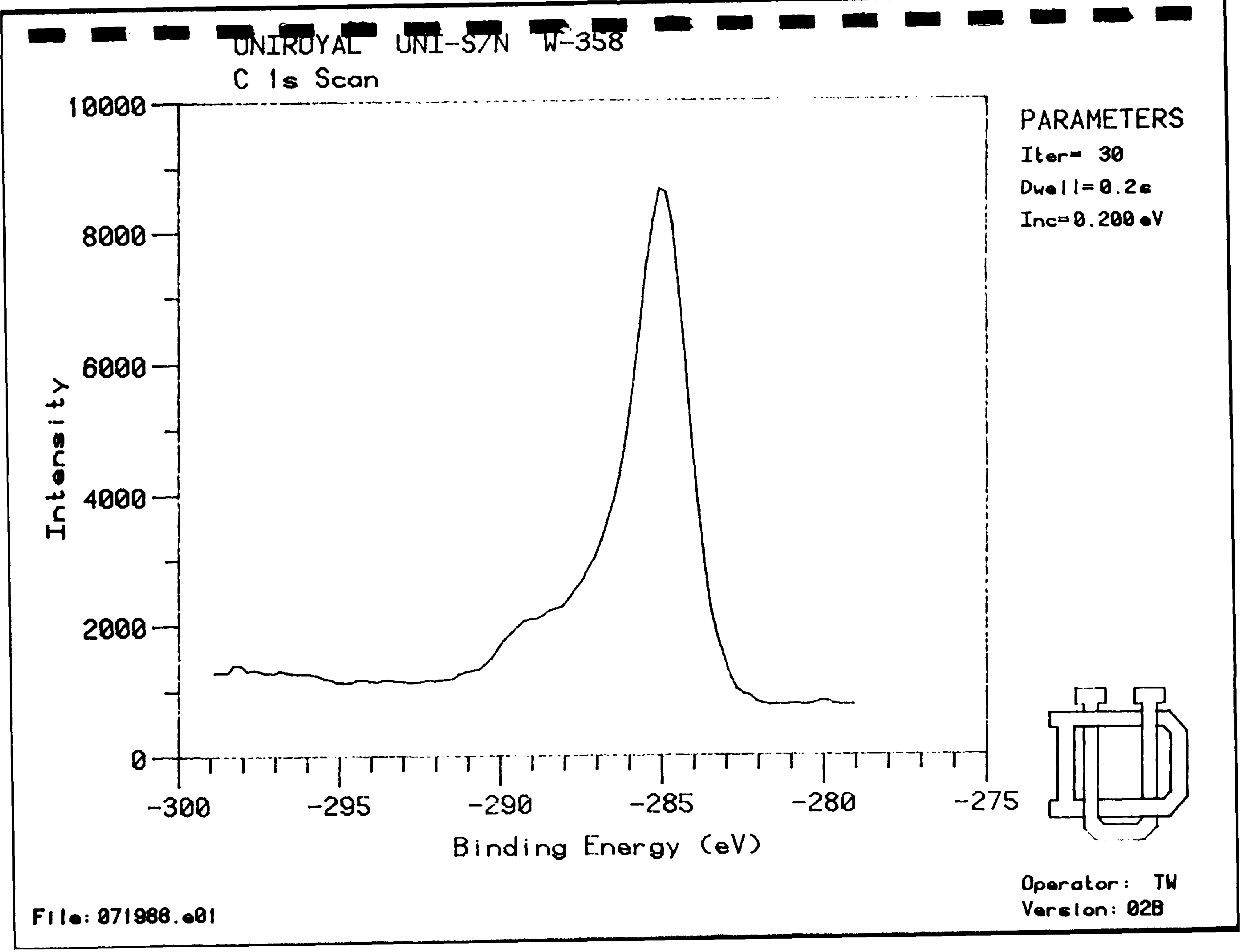
Inc=1.000eV



Operator: TW

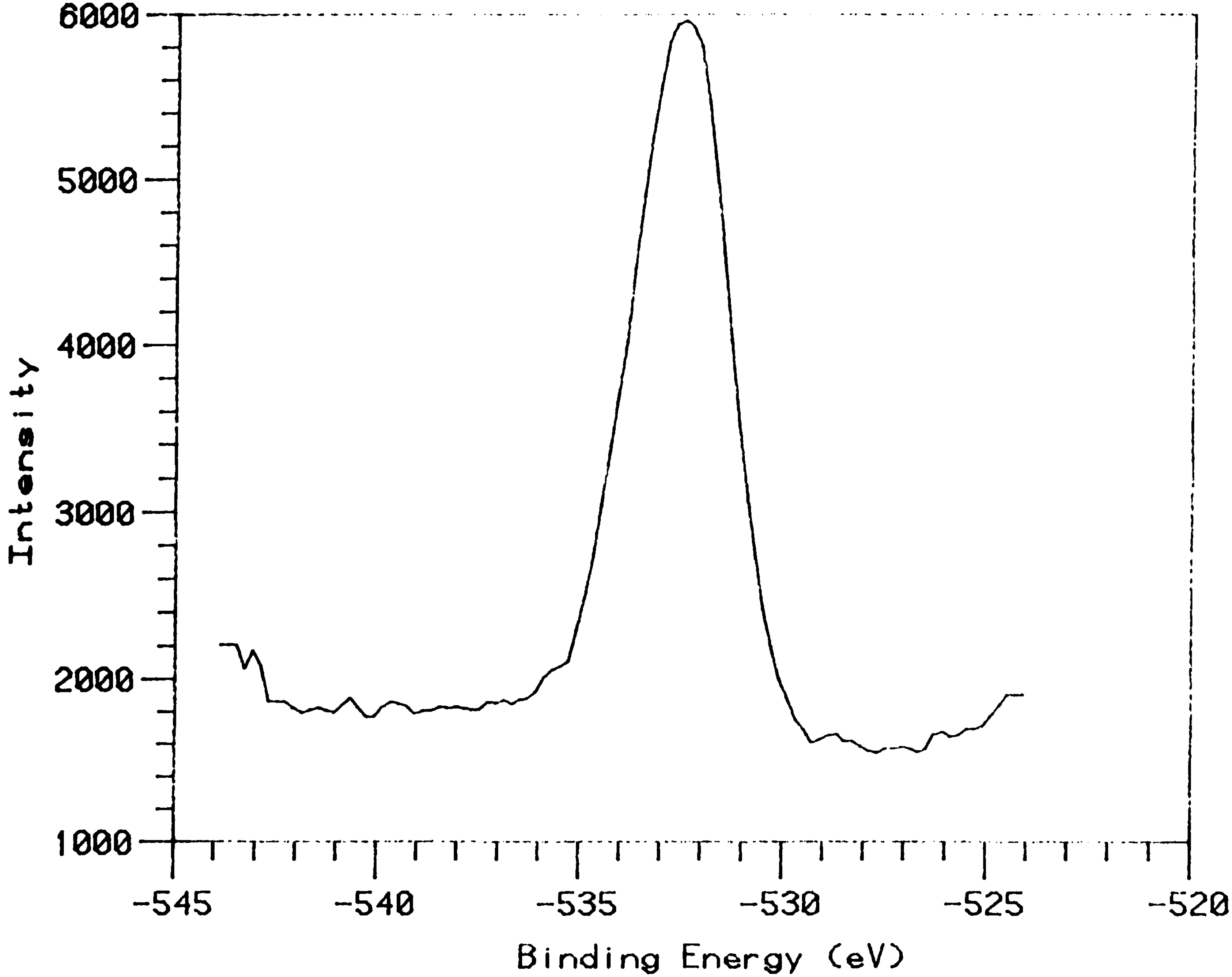
Version: 02B

File: 071988.e02


UNIROYAL UNI-S7N W-358
C 1s Scan
10000
8000
6000
4000
2000
0
Intensity
-300
-295
-290
-285
-280
-275
Binding Energy (eV)
PARAMETERS
Iter= 30
Dwell=0.2s
Inc=0.200eV
Operator: TW
Version: 02B
File: 071988.e01

UNIROYAL UNI-S/N W-358

O 1s Scan

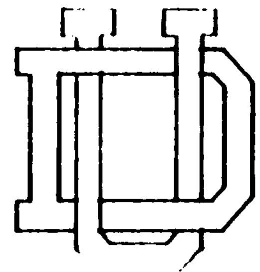


PARAMETERS

Iter= 30

Dwell=0.2s

Inc=0.200eV



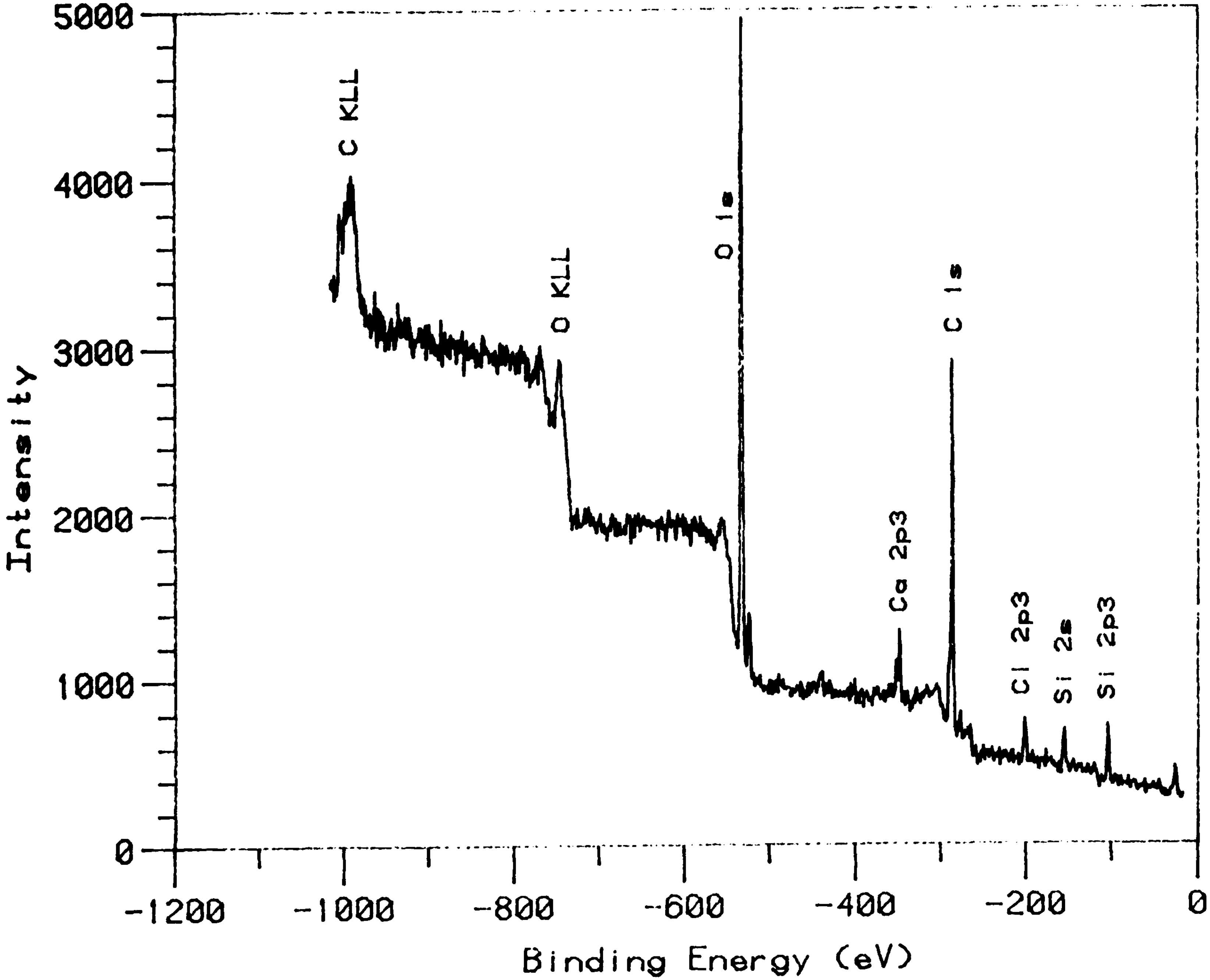
File: 071988.e01

Operator: TW

Version: 02B

UNIROYAL GDY-S7N 84-25727

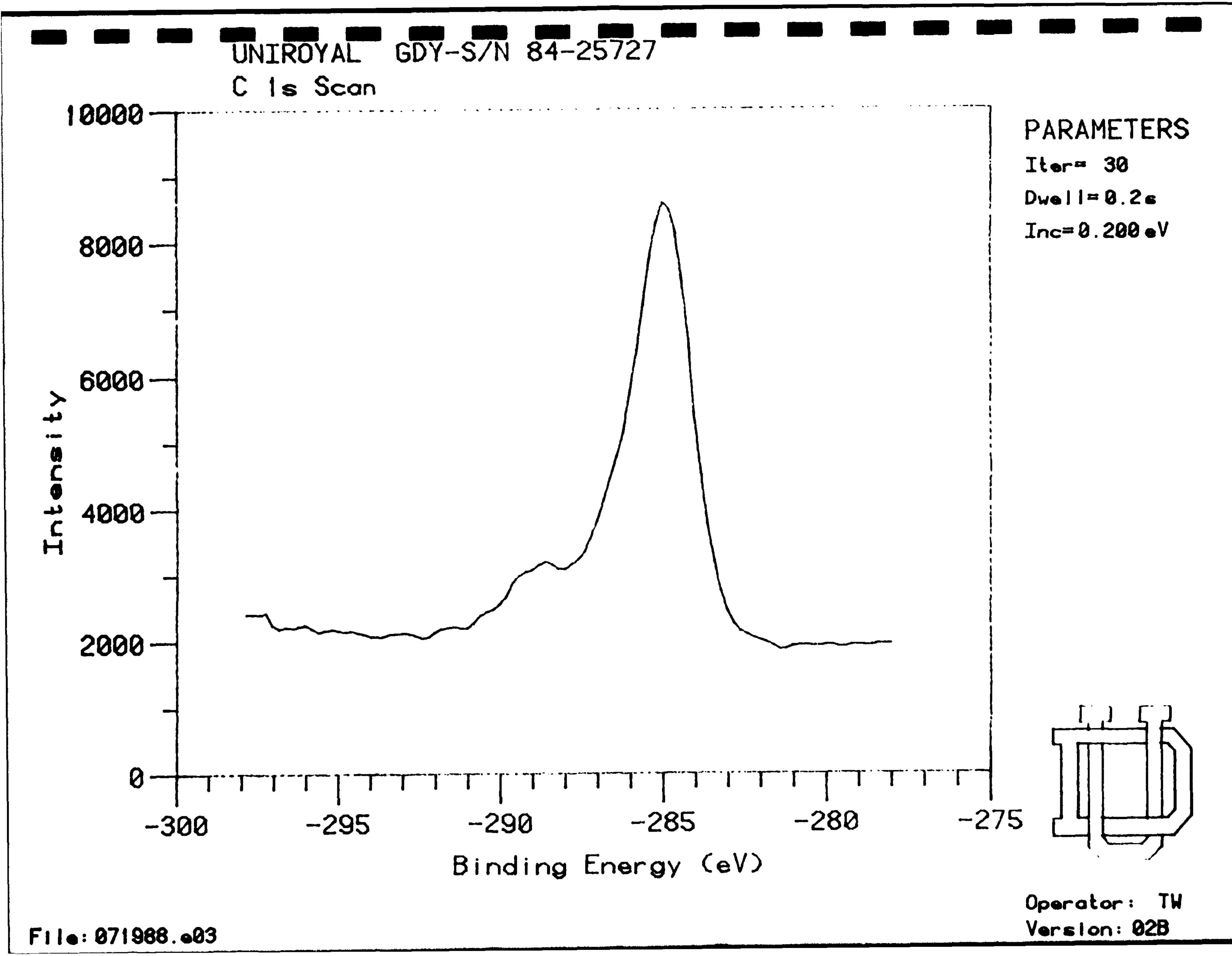
XPS Survey Scan



PARAMETERS
Iter= 10
Dwell=0.1s
Inc=1.000eV

Operator: TW
Version: 02B

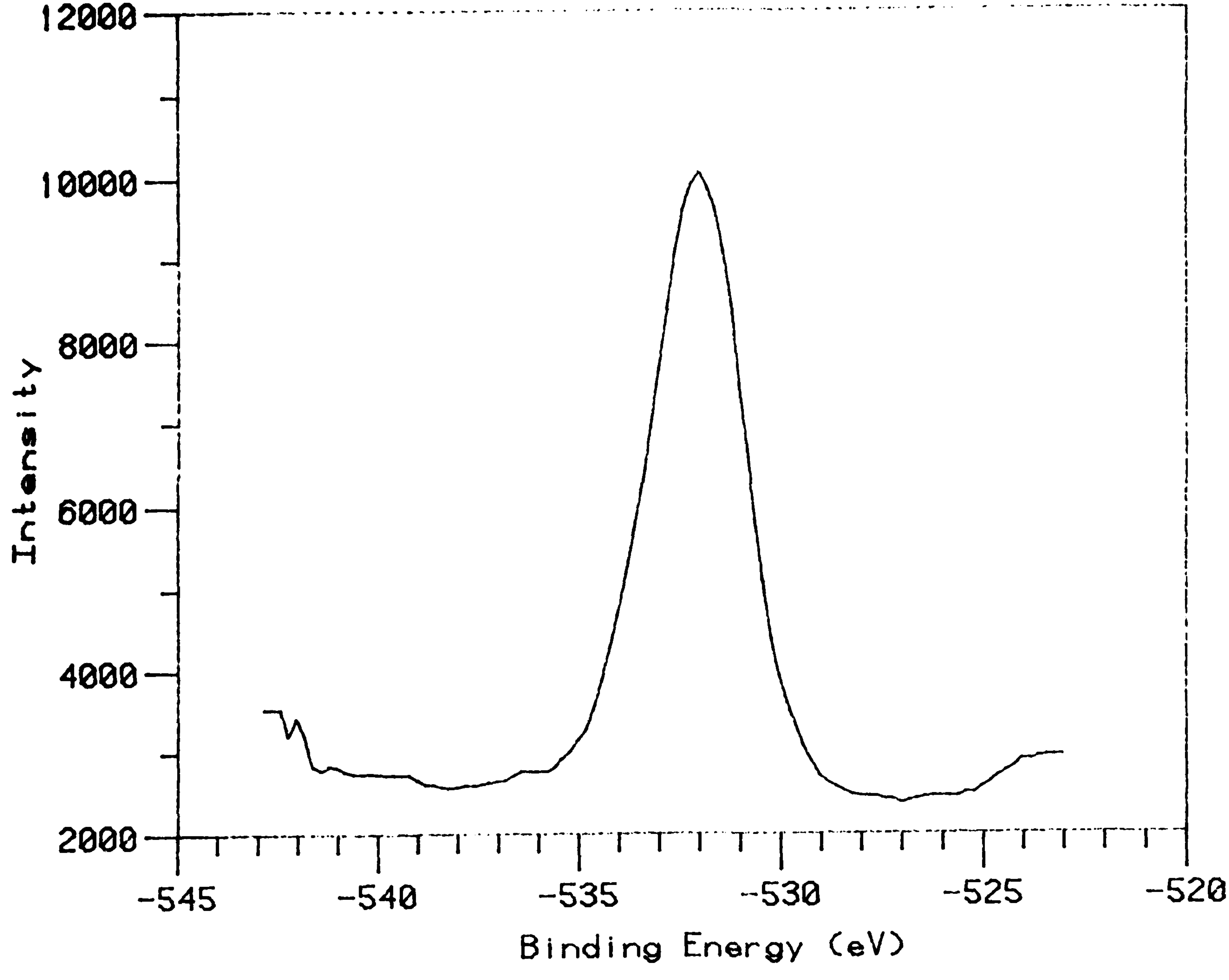
File: 071988.e04



UNIROYAL GDY-S/N 84-25727
C 1s Scan
PARAMETERS
Iter= 30
Dwell=0.2s
Inc=0.200eV
10000
8000
6000
4000
2000
0
Intensity
-300
-295
-290
-285
-280
-275
Binding Energy (eV)
Operator: TW
Version: 02B
File: 071988.e03

UNIROYAL GDY-S/N 84-25727

O 1s Scan



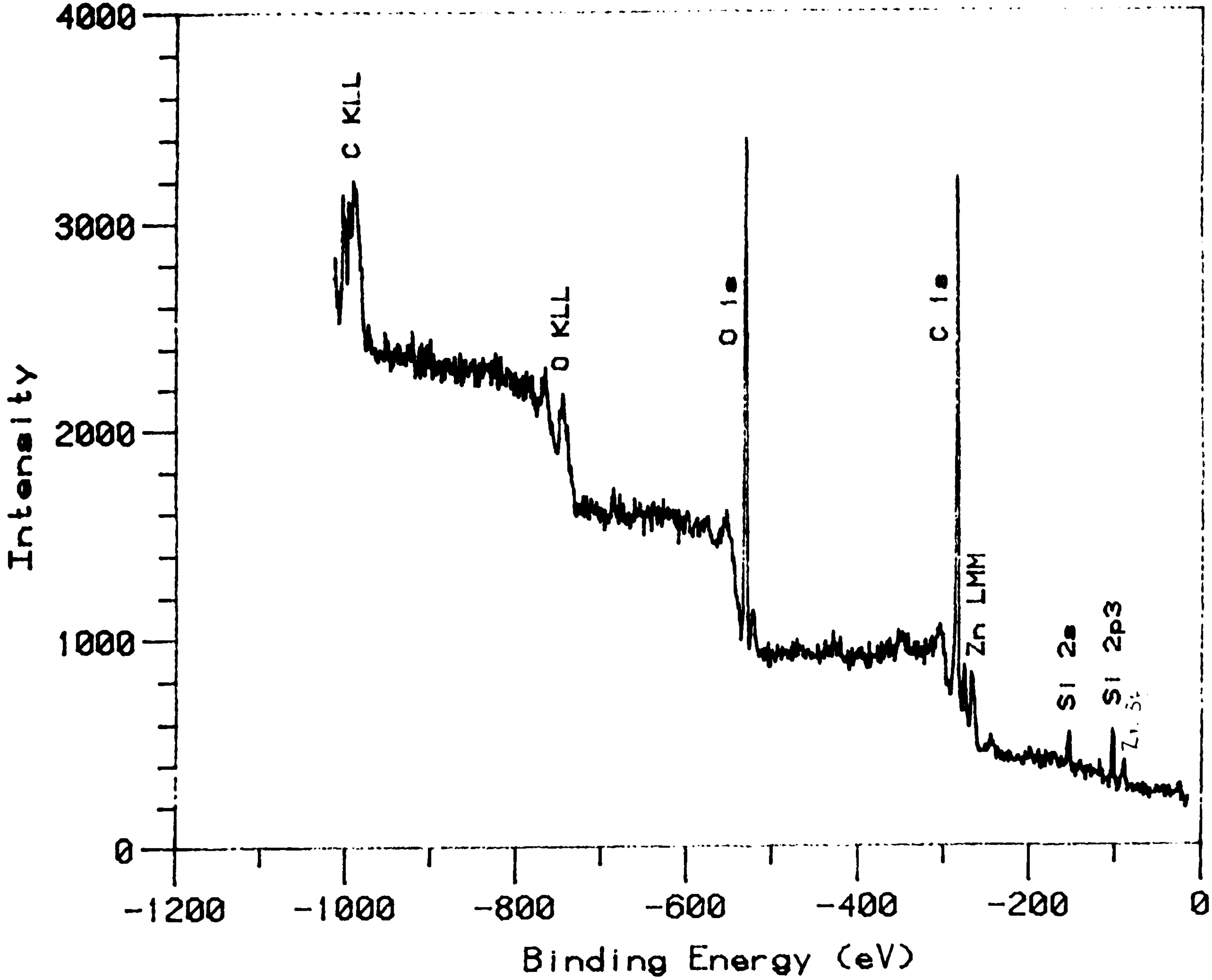
PARAMETERS
Iter= 26
Dwell=0.2s
Inc=0.200eV

Operator: TW
Version: 02B

File: 071988.e03

UNIROYAL UNI-S/N W-150

XPS Survey Scan

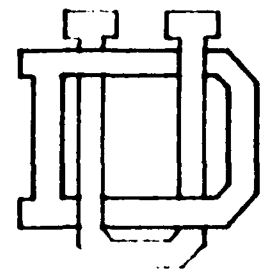


PARAMETERS

Iter= 10

Dwell=0.1s

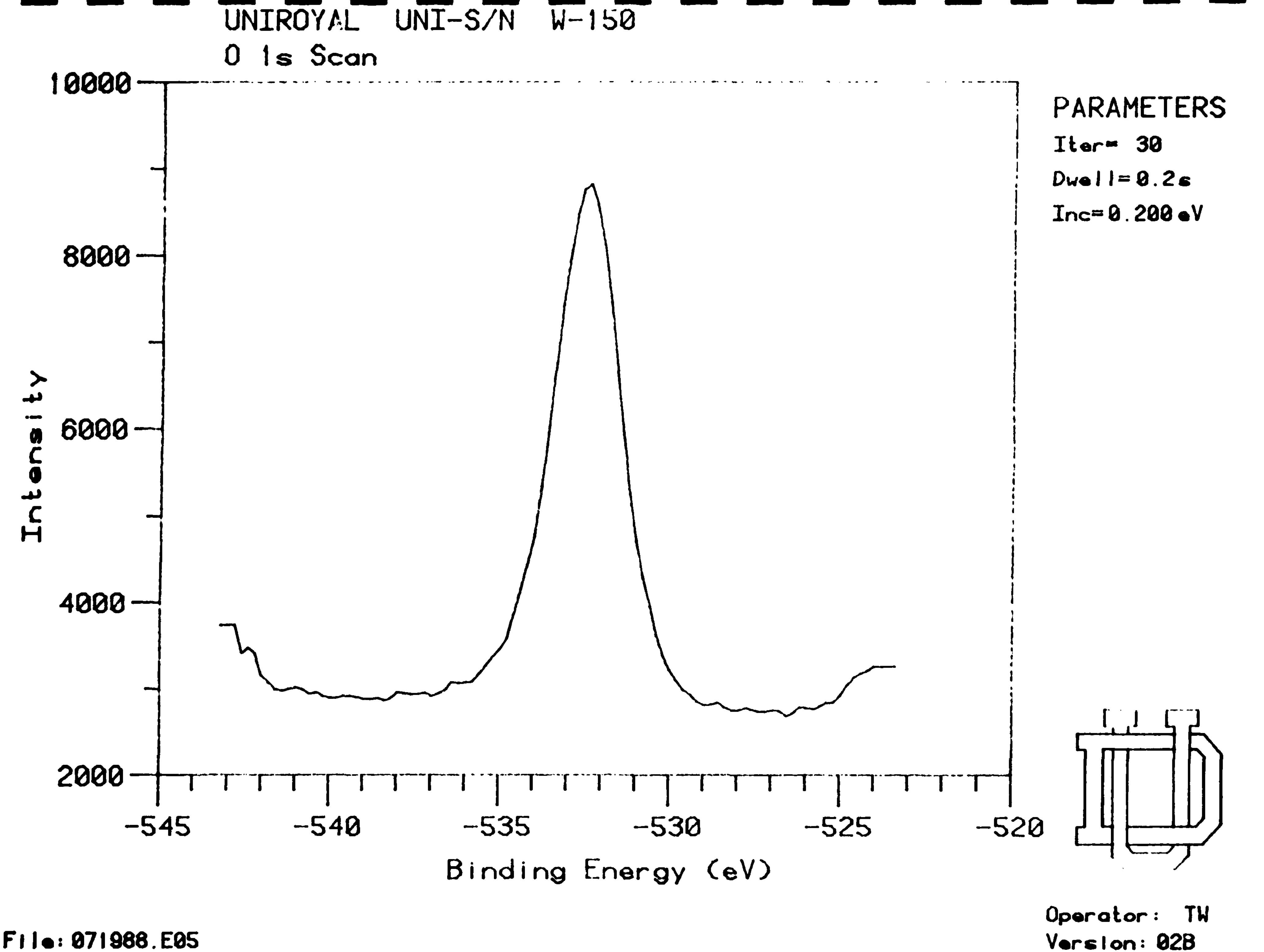
Inc=1.000 eV



Operator:

Version: 02B

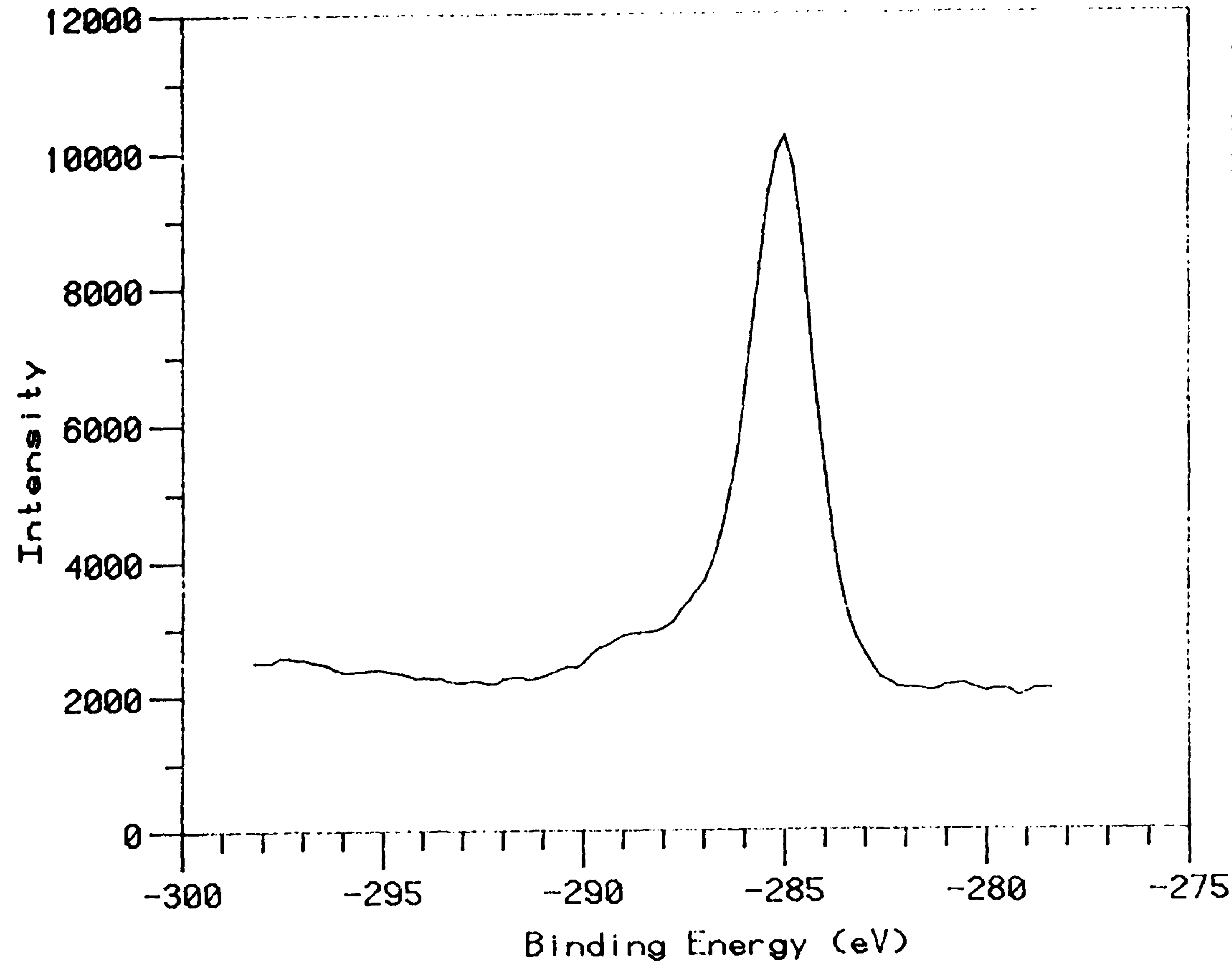
File: 071988.e06



UNIROYAL UNI-S/N W-150
O 1s Scan
PARAMETERS
Iter= 30
Dwell=0.2s
Inc=0.200 eV
10000
8000
6000
4000
2000
Intensity
-545
-540
-535
-530
-525
-520
Binding Energy (eV)
Operator: TW
Version: 02B
File: 071988.E05

UNIROYAL UNI-S/N W-150

C 1s Scan



PARAMETERS

Iter= 29

Dwell=0.2s

Inc=0.200eV

Operator: TW

Version: 02B

File: 071988.E05

The University of Dayton

1 March 1988

Mr. C. J, McNamara
Uniroyal Plastics Co., Inc.
312 North Hill St.
P. O. Box 2000
Mishawaka, Indiana 46544-1399

Dear Mr. McNamara:

I have used XPS (x-ray photoelectron spectroscopy) to analyze the elastomer samples that we received from you last week. In all cases the surface facing away from the white paper was analyzed. I should perhaps mention again that XPS is a surface-sensitive technique which can detect all elements (except hydrogen and helium) present at levels > 0.5% within 30 Å of a sample surface.

For each of the nine samples I recorded spectra of the carbon 1s and oxygen 1s photoelectron pecks. The following table gives the carbon-to-oxygen atom % ratio for each sample as determined from these spectra.

Sample	% Carbon / % Oxygen
UNI - S/N W-150	6.8
UNI - 3K S/N 6	3.4
UNI - 50K S/N W-122	5.3
S/N - 1109	2.4
UNI - 10K S/N 510	2.9
UNI - S/N W-9	2.3
GDY - S/N 84-2572	5.7
20K - S/N W-1	5.0
10K - S/N W-2	6.9

On the samples with the highest oxygen levels (eg. S/N 1109, S/N 510 and S/N W-9), the carbon 1s spectra showed strong shoulders due to C-O and C=O type carbon. I did not attempt to resolve the overlapping components of the carbon spectra although this could be easily done with the software that we have.

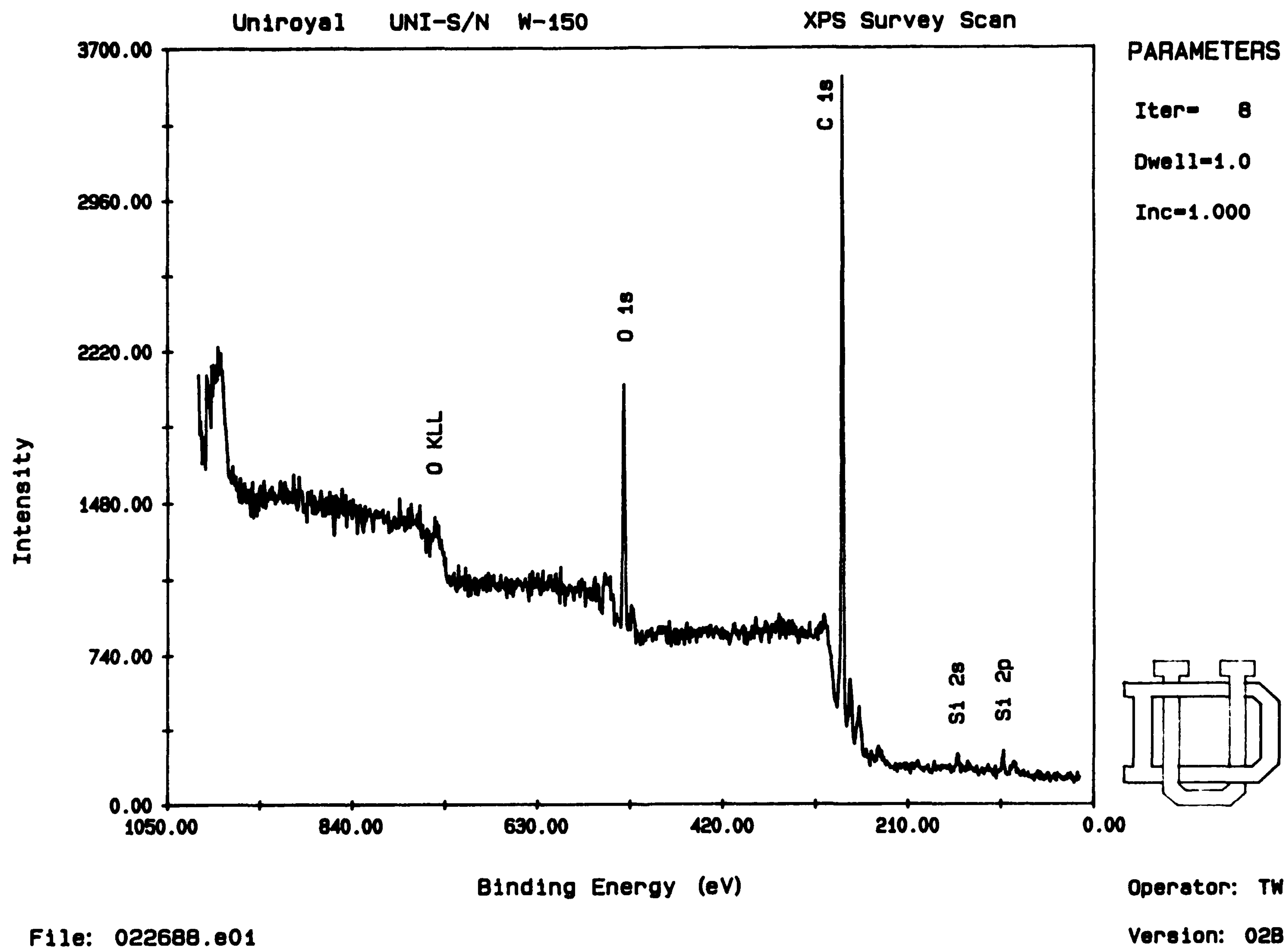
On each of the samples I recorded a brief survey scan to check for other elements that might be present. As you can see from the enclosed data, other elements such as nitrogen, zinc, silicon and fluorine are detected on all of the samples.

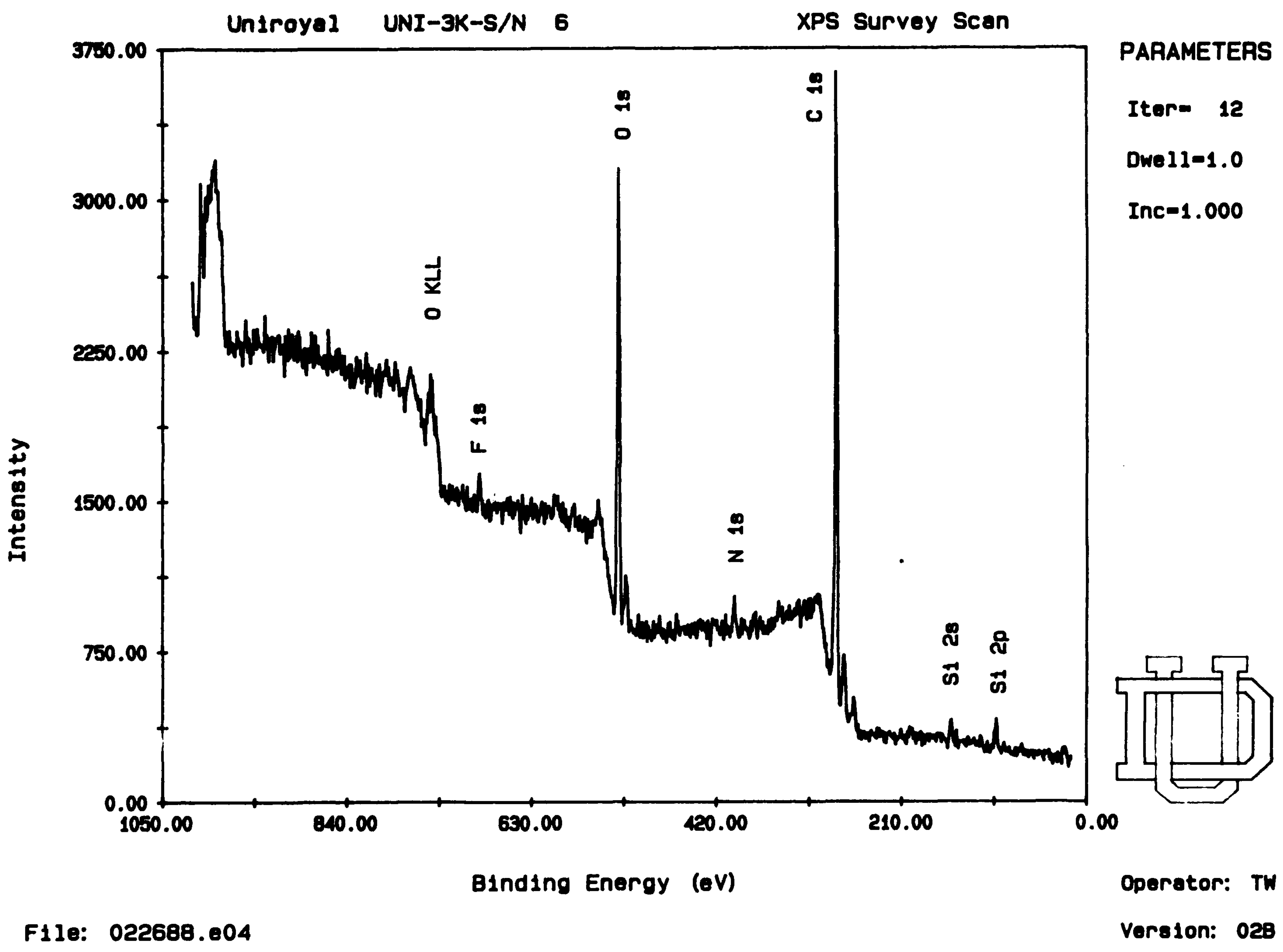
Sincerely,

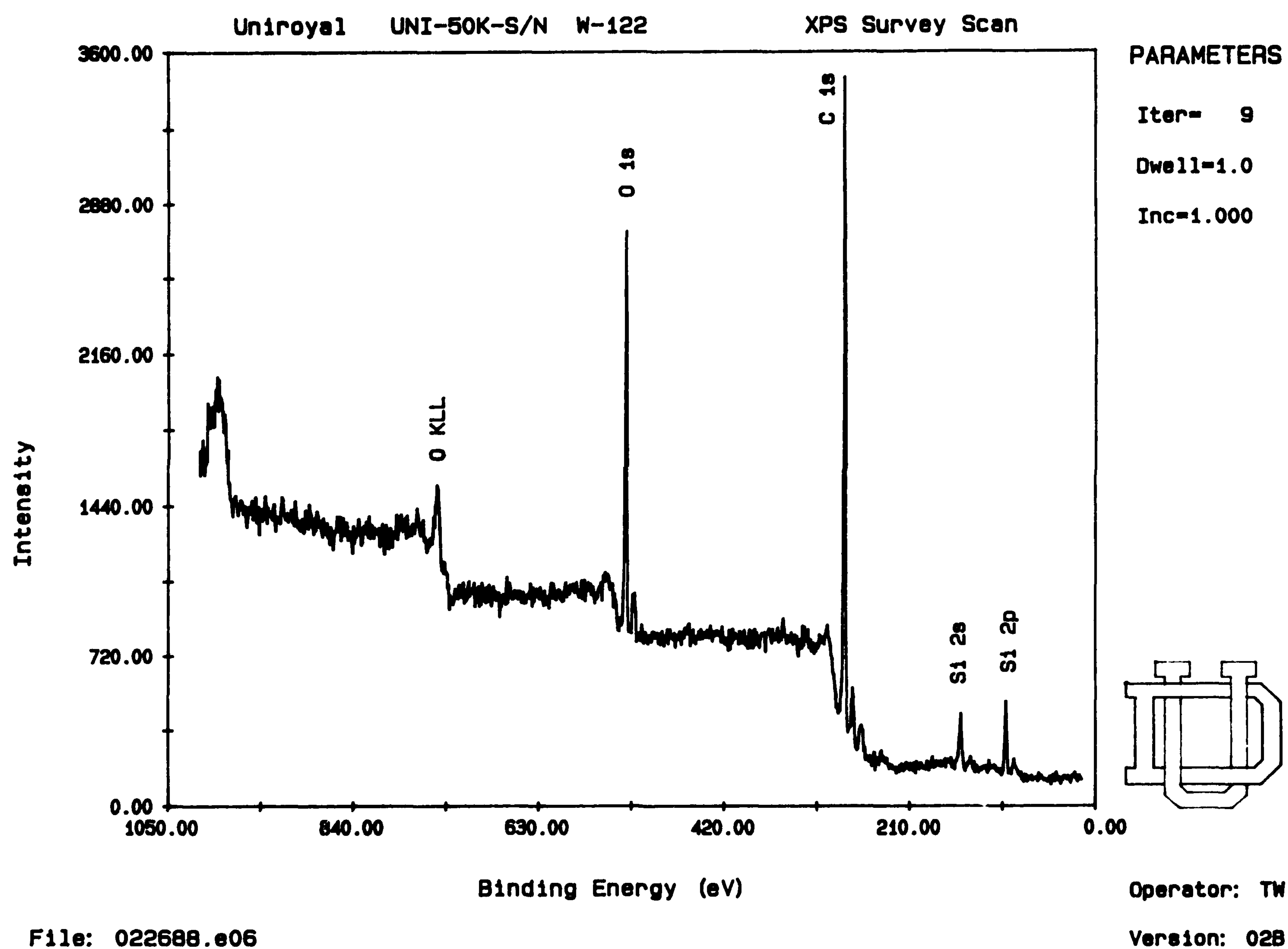
Tom Wittberg

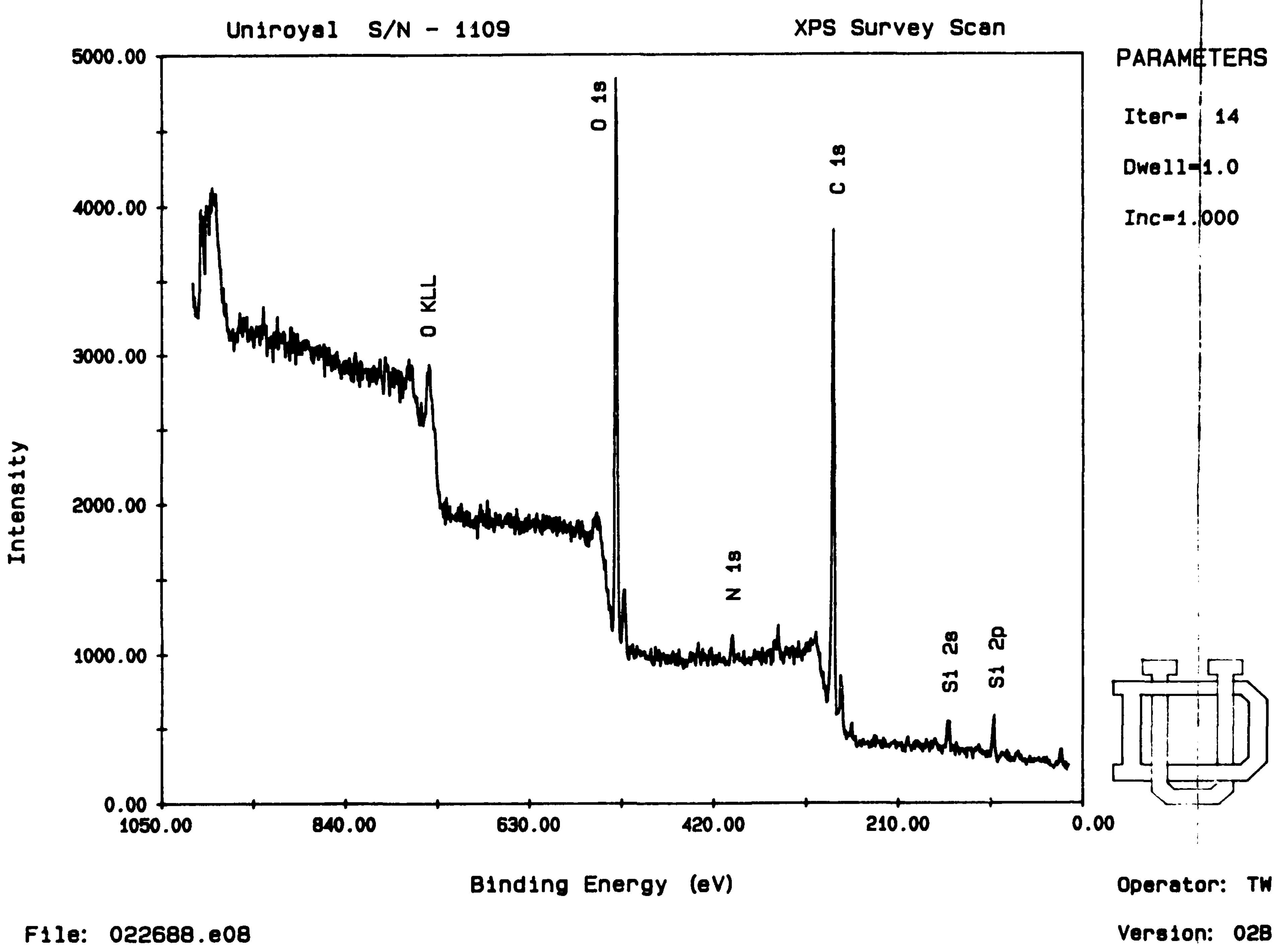
Tom Wittberg

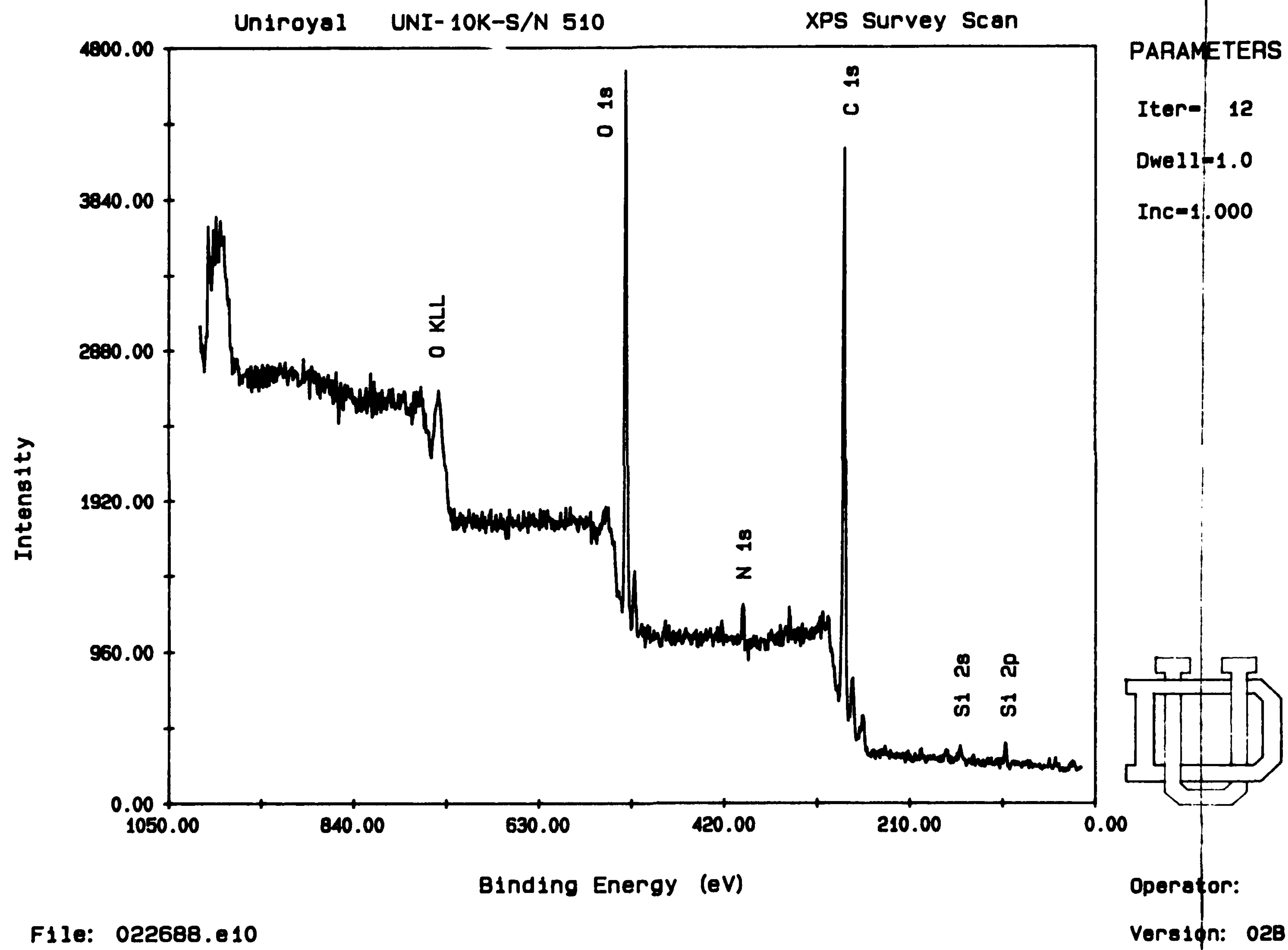
Enclosures


Uniroyal UNI-S/N W-150
XPS Survey Scan
PARAMETERS
Iter= 8
Dwell=1.0
Inc=1.000
3700.00
2960.00
2220.00
1480.00
740.00
0.00
Intensity
C 1s
O 1s
O KLL
Si 2s
Si 2p
1050.00
840.00
630.00
420.00
210.00
0.00
Binding Energy (eV)
Operator: TW
Version: 02B
File: 022688.e01

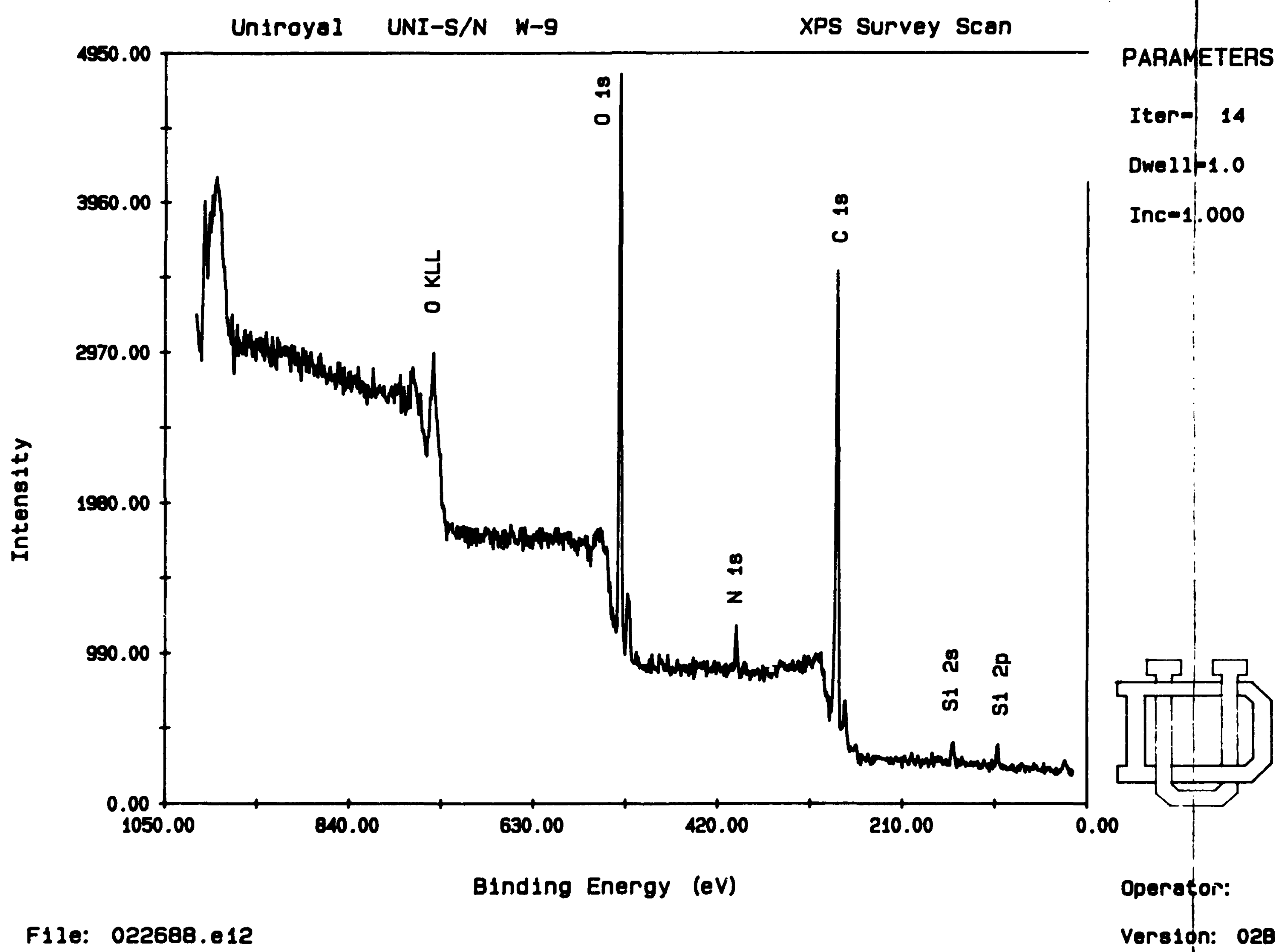

Uniroyal UNI-3K-S/N 6
XPS Survey Scan
PARAMETERS
Iter= 12
Dwell=1.0
Inc=1.000
3750.00
3000.00
2250.00
1500.00
750.00
0.00
Intensity
O KLL
F 1s
O 1s
N 1s
C 1s
Si 2s
Si 2p
1050.00
840.00
630.00
420.00
210.00
0.00
Binding Energy (eV)
Operator: TW
File: 022688.e04
Version: 02B

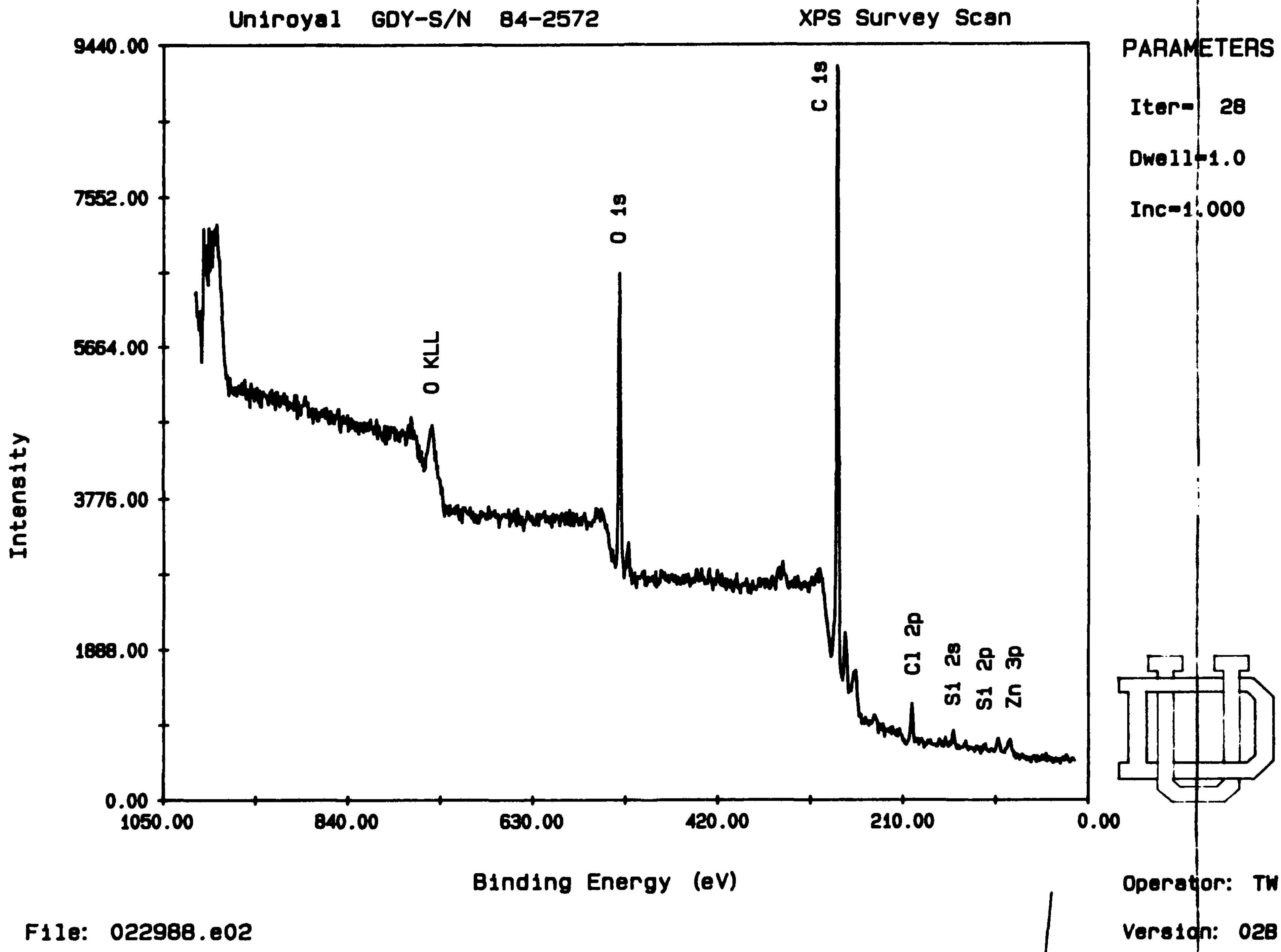

Uniroyal UNI-50K-S/N W-122
XPS Survey Scan
PARAMETERS
Iter= 9
Dwell=1.0
Inc=1.000
Intensity
3600.00
2880.00
2160.00
1440.00
720.00
0.00
1050.00
840.00
630.00
420.00
210.00
0.00
O KLL
O 1s
C 1s
Si 2s
Si 2p
Binding Energy (eV)
Operator: TW
File: 022688.e06
Version: 02B


Uniroyal S/N - 1109
XPS Survey Scan
PARAMETERS
Iter= 14
Dwell=1.0
Inc=1.000
5000.00
4000.00
3000.00
2000.00
1000.00
0.00
Intensity
O 1s
C 1s
O KLL
N 1s
Si 2s
Si 2p
1050.00
840.00
630.00
420.00
210.00
0.00
Binding Energy (eV)
Operator: TW
File: 022688.e08
Version: 02B

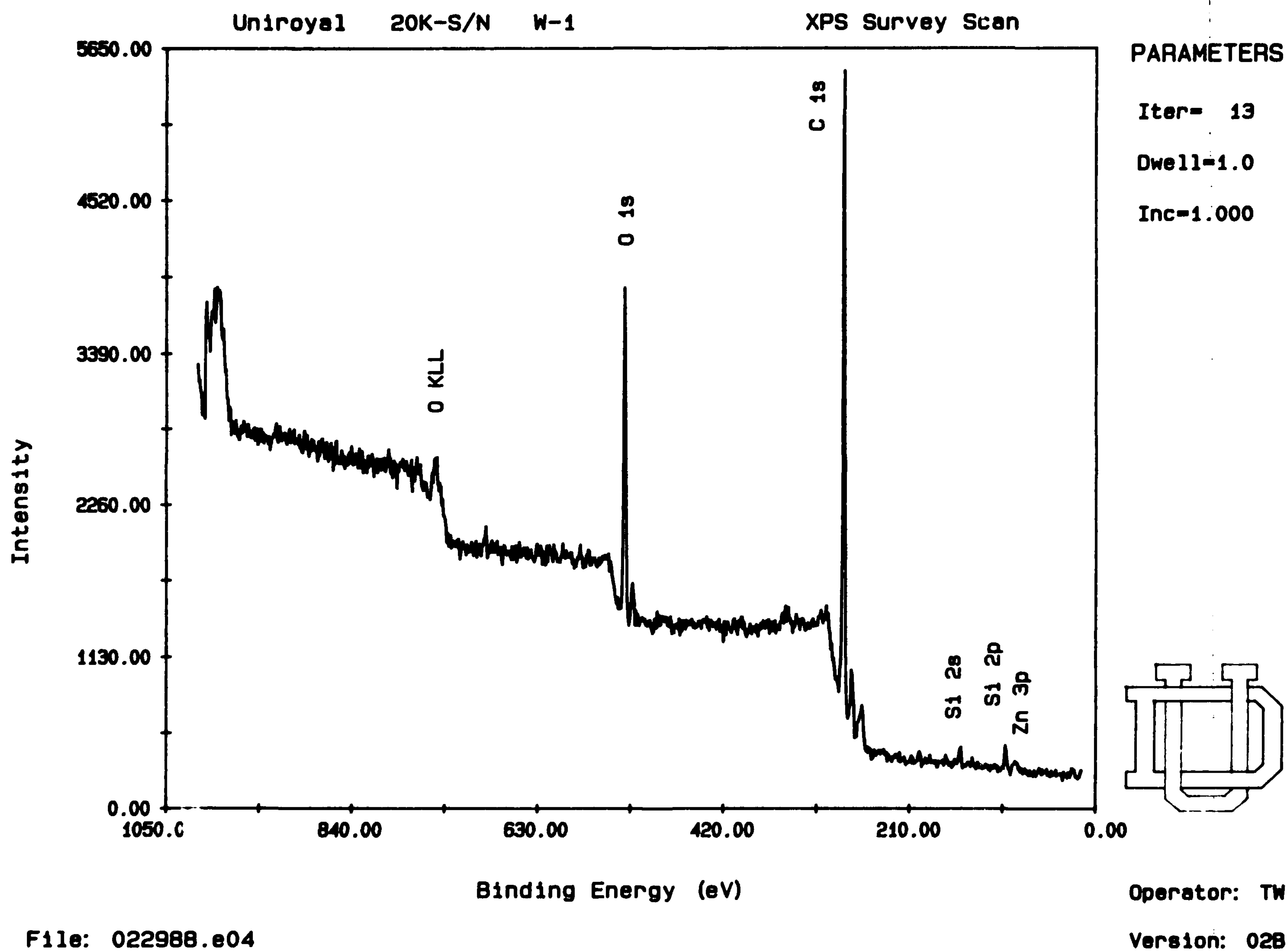


Uniroyal UNI-10K-S/N 510
XPS Survey Scan
4800.00
3840.00
2880.00
1920.00
960.00
0.00
Intensity
O KLL
O 1s
N 1s
C 1s
Si 2s
Si 2p
1050.00
840.00
630.00
420.00
210.00
0.00
Binding Energy (eV)
File: 022688.e10
PARAMETERS
Iter= 12
Dwell=1.0
Inc=1.000
Operator:
Version: 02B

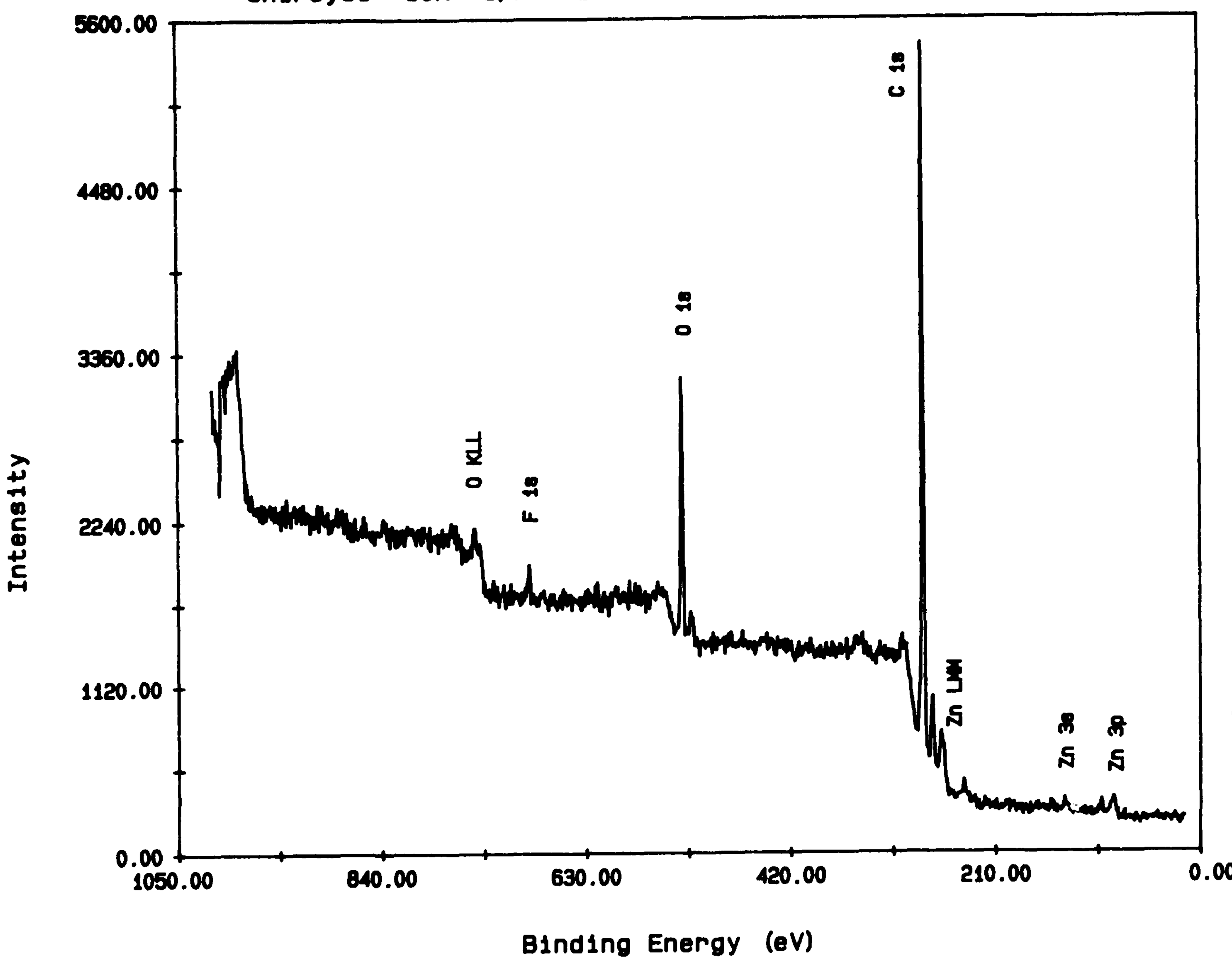

Uniroyal UNI-S/N W-9
XPS Survey Scan
PARAMETERS
Iter= 14
Dwell=1.0
Inc=1.000
Intensity
4950.00
3960.00
2970.00
1980.00
990.00
0.00
1050.00
840.00
630.00
420.00
210.00
0.00
Binding Energy (eV)
O KLL
O 1s
N 1s
C 1s
Si 2s
Si 2p
Operator:
Version: 02B
File: 022688.e12



Uniroyal GDY-S/N 84-2572
XPS Survey Scan
PARAMETERS
Iter= 28
Dwell=1.0
Inc=1.000
9440.00
7552.00
5664.00
3776.00
1888.00
0.00
Intensity
1050.00
840.00
630.00
420.00
210.00
0.00
Binding Energy (eV)
C 1s
O 1s
O KLL
Cl 2p
Si 2s
Si 2p
Zn 3p
Operator: TW
Version: 028
File: 022988.e02



Uniroyal 20K-S/N W-1
XPS Survey Scan
PARAMETERS
Iter= 13
Dwell=1.0
Inc=1.000
5650.00
4520.00
3390.00
2260.00
1130.00
0.00
Intensity
C 1s
O 1s
O KLL
Si 2s
Si 2p
Zn 3p
1050.0
840.00
630.00
420.00
210.00
0.00
Binding Energy (eV)
Operator: TW
Version: 028
File: 022988.e04



PARAMETERS

Iter= 12

Dwell=1.0

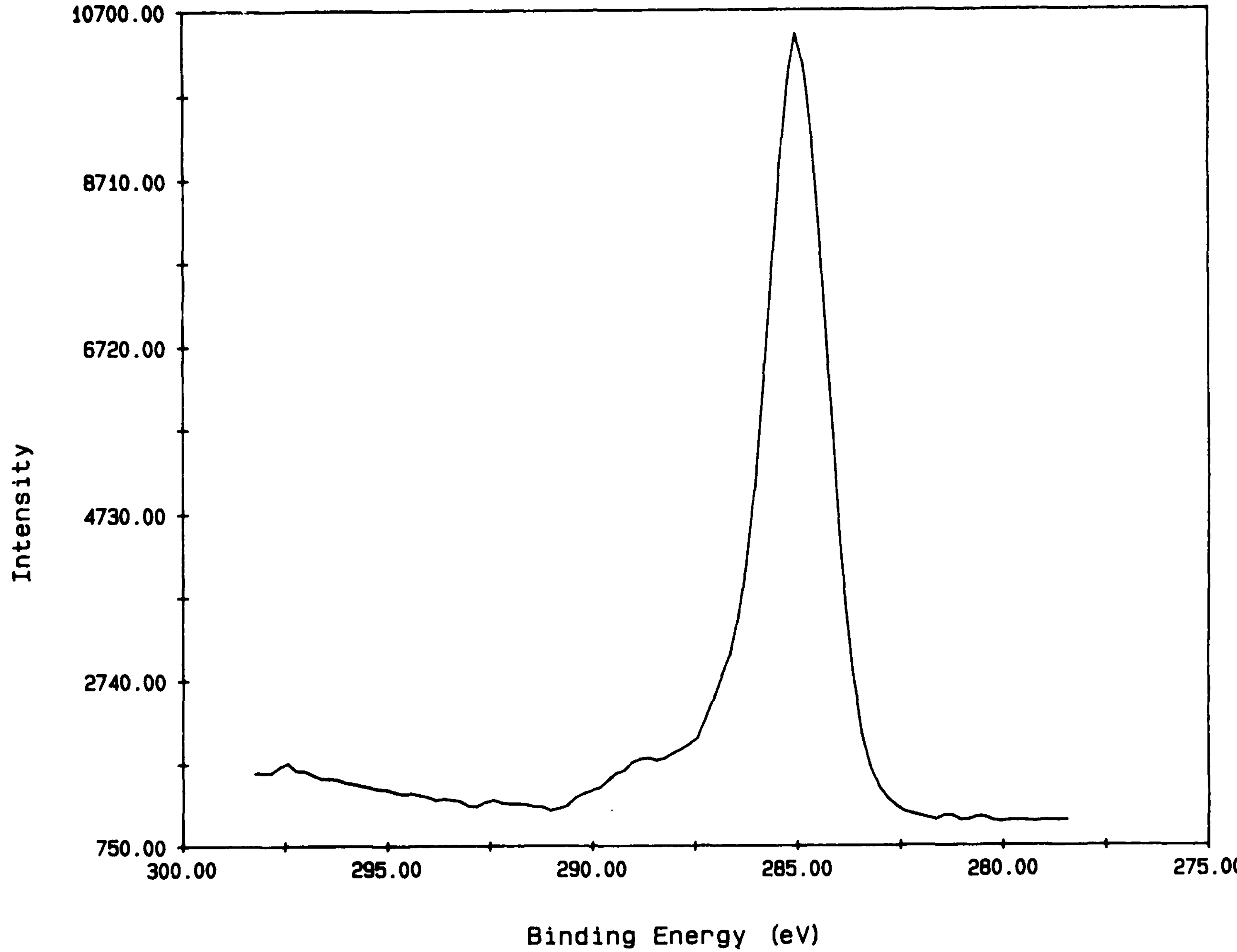
Inc=1.000

Operator: TW

Version: 02B

File: 022988.E06

Uniroyal UNI-S/N W-150 C 1s Scan



PARAMETERS

Iter= 23

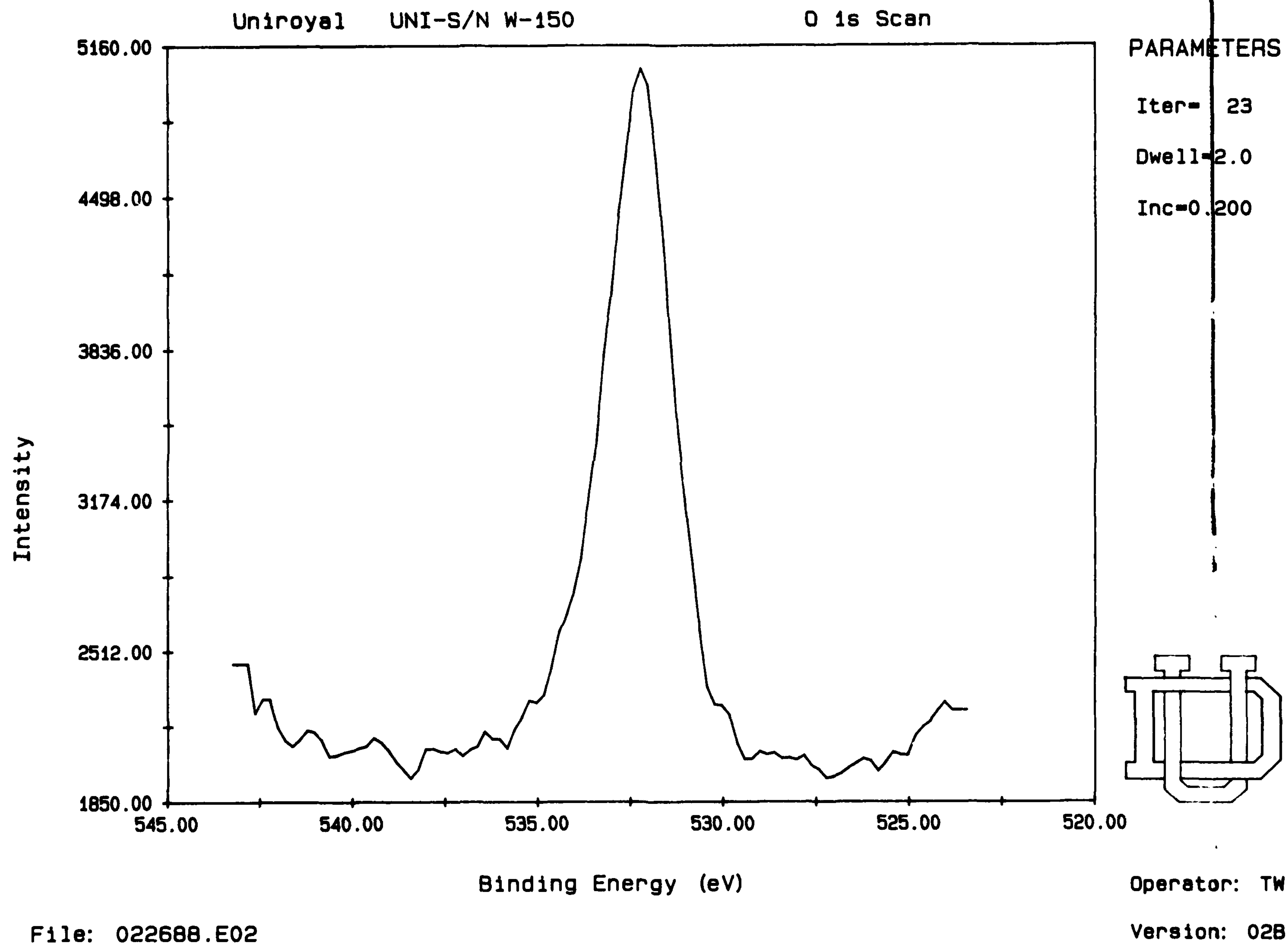
Dwell=2.0

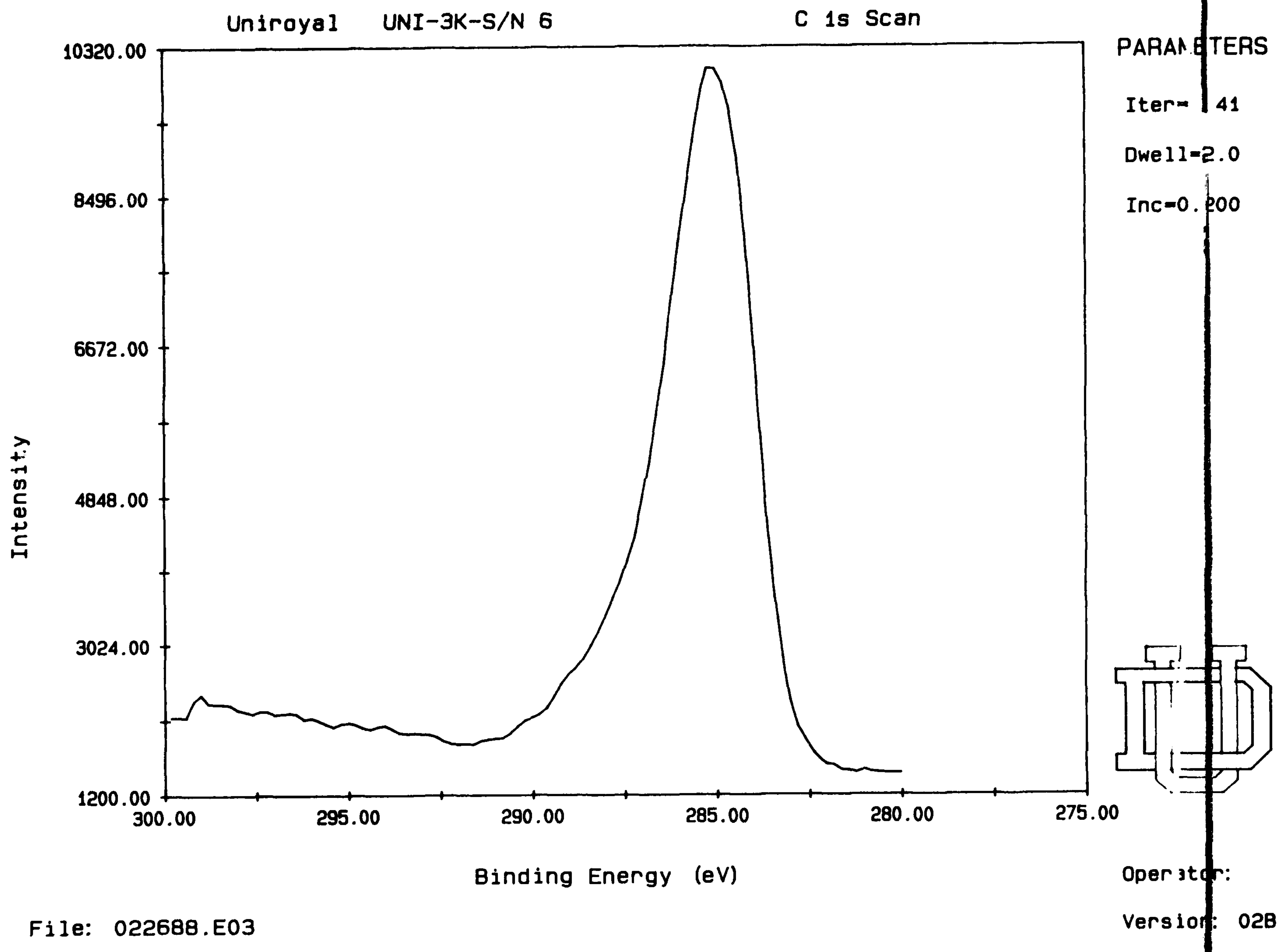
Inc=0.200

File: 022688.E02

Operator: TW

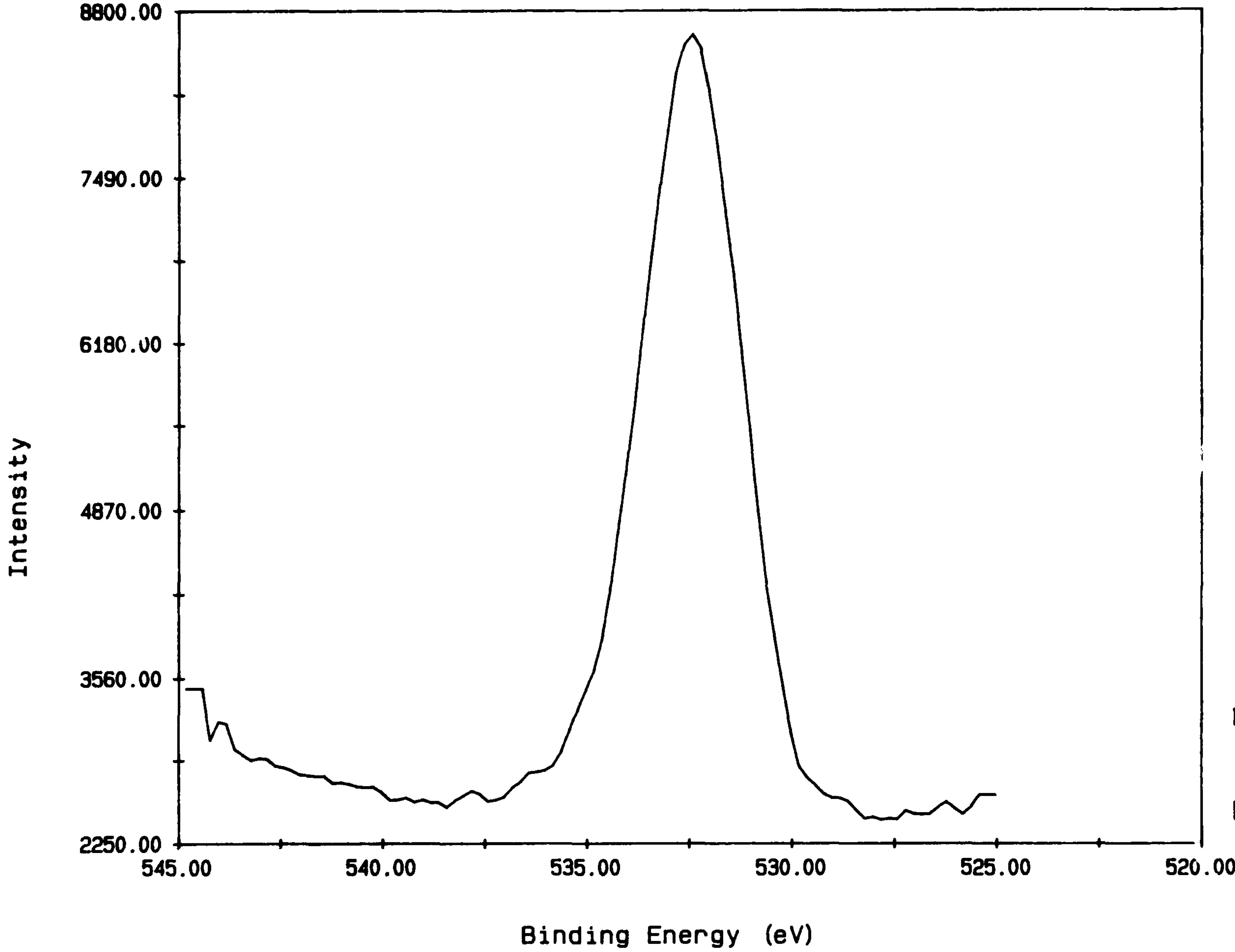
Version: 02B


Uniroyal UNI-S/N W-150
O 1s Scan
PARAMETERS
Iter= 23
Dwell=2.0
Inc=0.200
Intensity
5160.00
4498.00
3836.00
3174.00
2512.00
1850.00
545.00
540.00
535.00
530.00
525.00
520.00
Binding Energy (eV)
Operator: TW
Version: 02B
File: 022688.E02



Uniroyal UNI-3K-S/N 6
C 1s Scan
PARAMETERS
Iter= 41
Dwell=2.0
Inc=0.200
10320.00
8496.00
6672.00
4848.00
3024.00
1200.00
Intensity
300.00
295.00
290.00
285.00
280.00
275.00
Binding Energy (eV)
Operator:
Version: 02B
File: 022688.E03

Uniroyal UNI-3K-S/N 6 O 1s Scan



PARAMETERS

Iter= 40

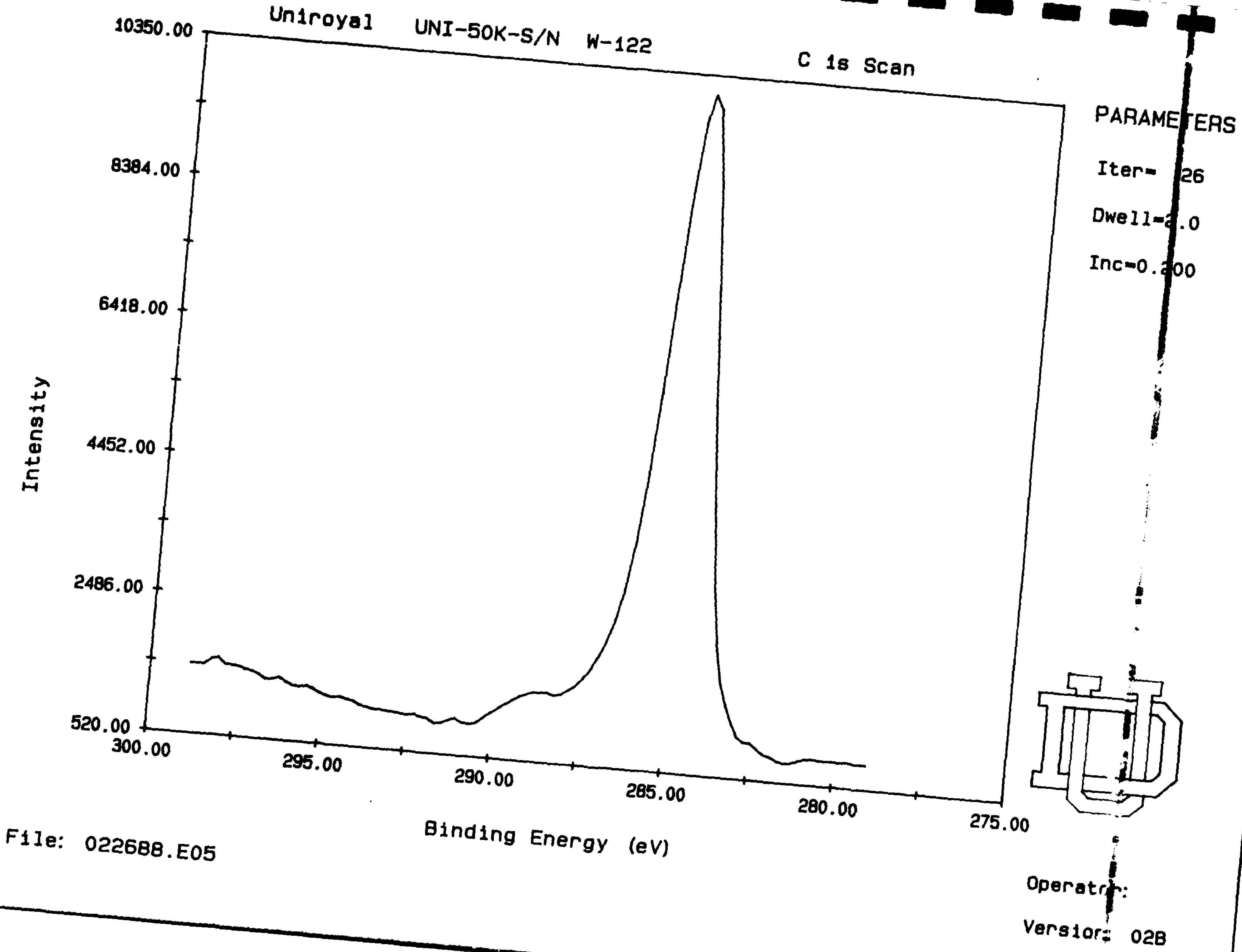
Dwell=[illegible].0

Inc=0.[illegible]00

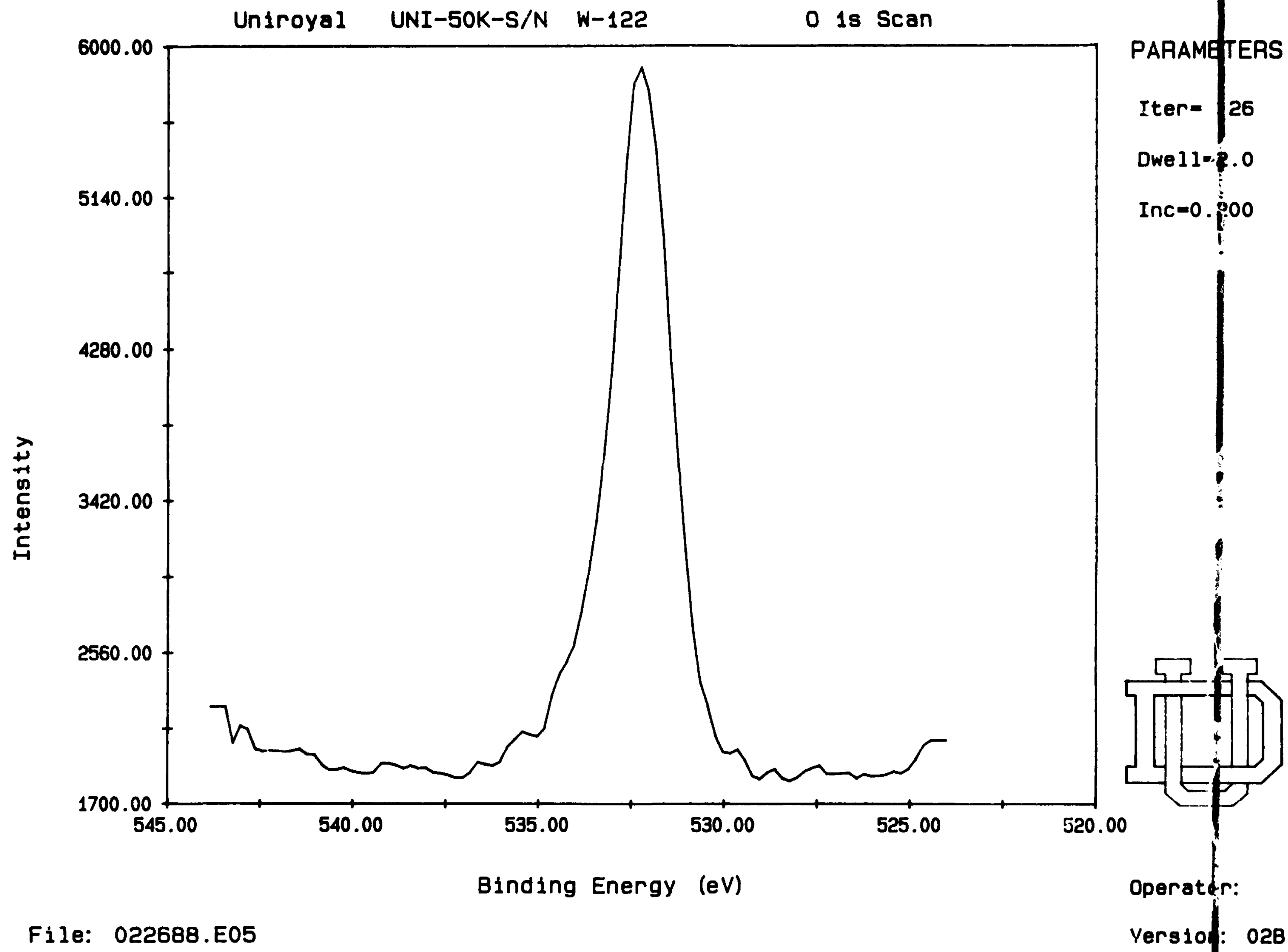
File: 022688.E03

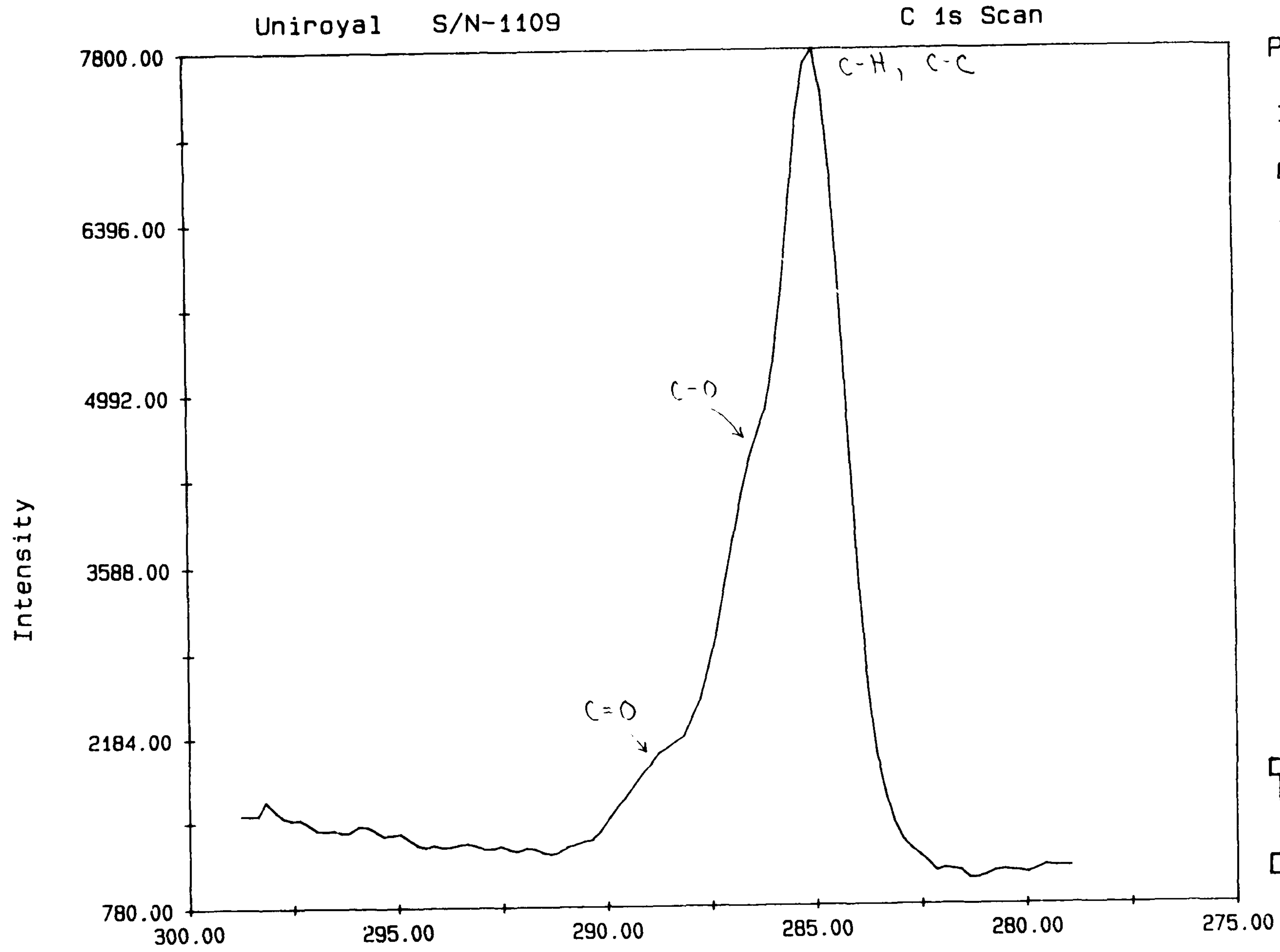
Operator:

Version 02B



Uniroyal UNI-50K-S/N W-122
C 1s Scan
Intensity
10350.00
8384.00
6418.00
4452.00
2486.00
520.00
300.00
295.00
290.00
285.00
280.00
275.00
Binding Energy (eV)
PARAMETERS
Iter= 26
Dwell=2.0
Inc=0.200
File: 022688.E05
Operator:
Version: 02B


Uniroyal UNI-50K-S/N W-122 O 1s Scan
6000.00
5140.00
4280.00
3420.00
2560.00
1700.00
Intensity
545.00
540.00
535.00
530.00
525.00
520.00
Binding Energy (eV)
PARAMETERS
Iter= 26
Dwell=2.0
Inc=0.200
Operater:
Version: 02B
File: 022688.E05



PARAMETERS

Iter= 30

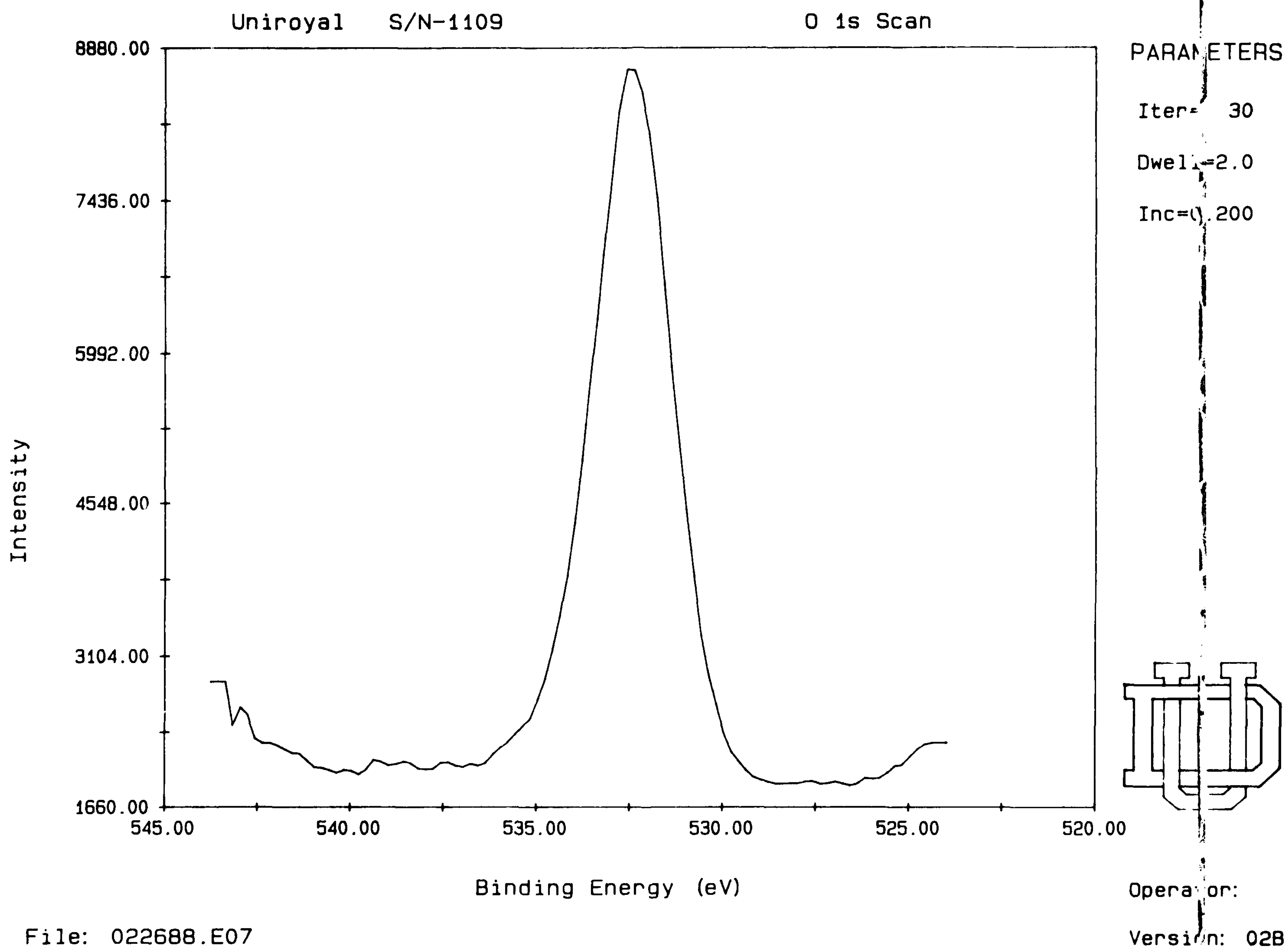
Dwell=2.0

Inc=0.200

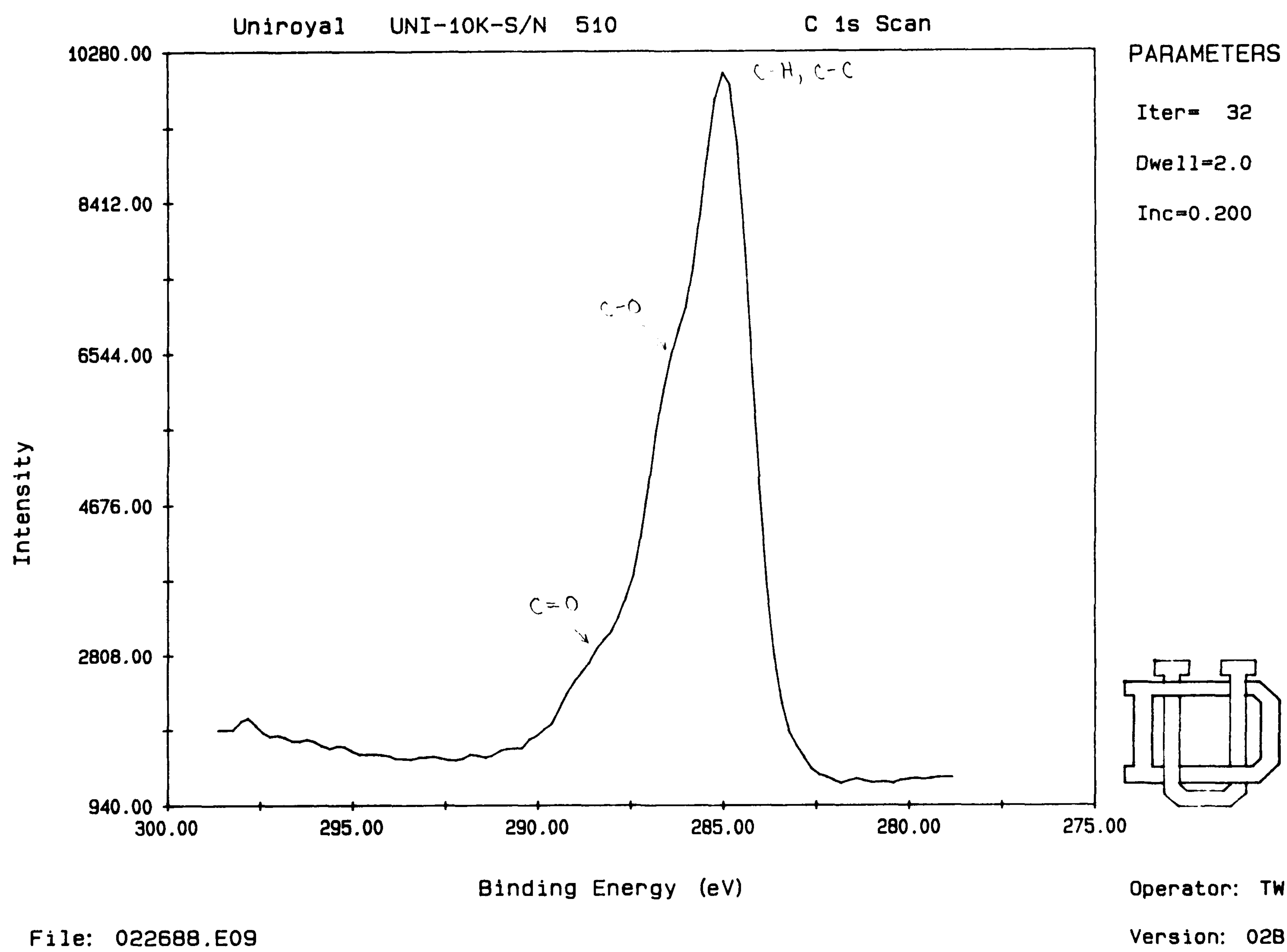
Operator:

Version: 02B

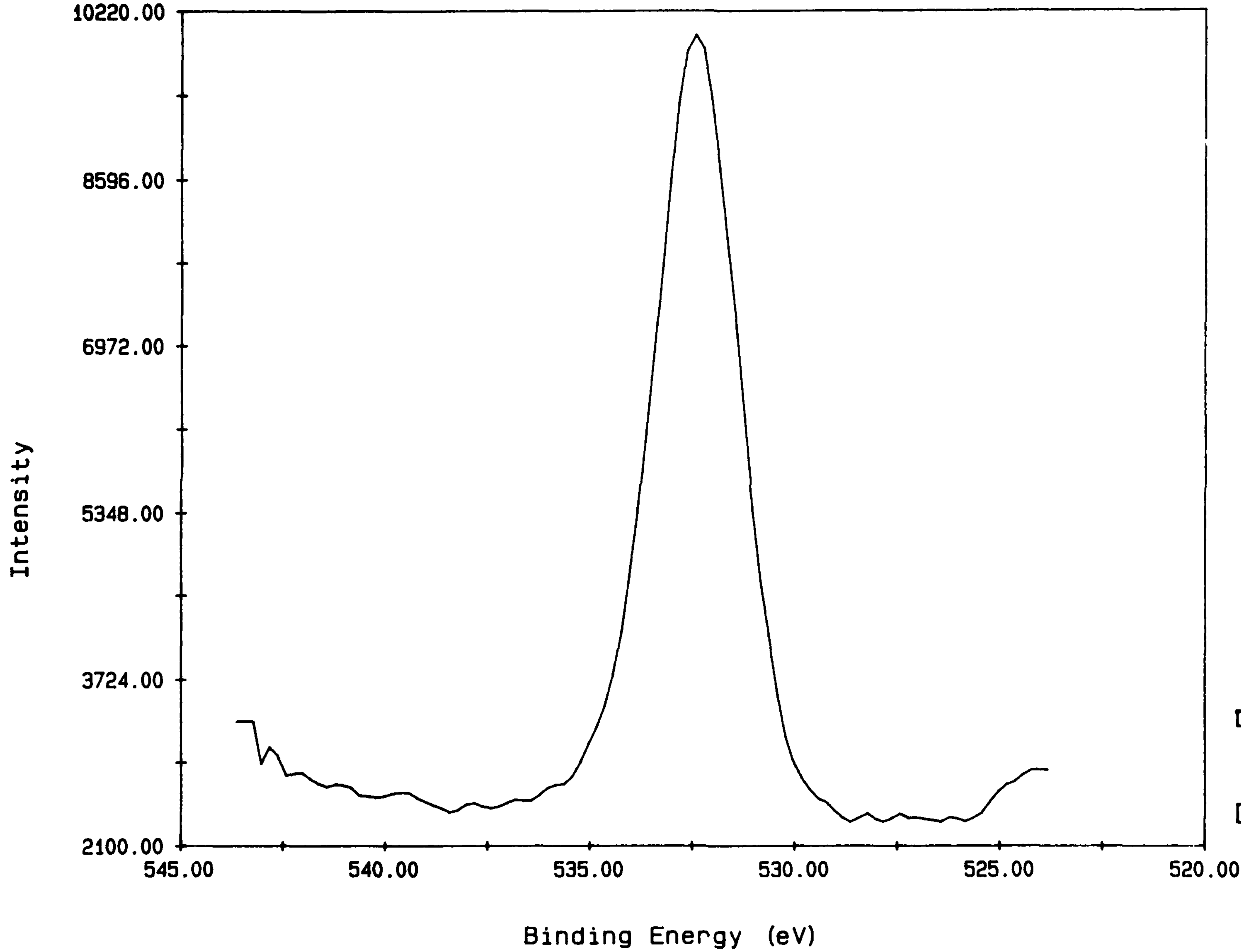
File: 022688.E07



Uniroyal S/N-1109
O 1s Scan
PARAMETERS
Iter= 30
Dwell=2.0
Inc=0.200
Intensity
8880.00
7436.00
5992.00
4548.00
3104.00
1660.00
545.00
540.00
535.00
530.00
525.00
520.00
Binding Energy (eV)
Operator:
Version: 02B
File: 022688.E07


Uniroyal UNI-10K-S/N 510
C 1s Scan
10280.00
8412.00
6544.00
4676.00
2808.00
940.00
Intensity
C-H, C-C
C-O
C=O
300.00
295.00
290.00
285.00
280.00
275.00
Binding Energy (eV)
PARAMETERS
Iter= 32
Dwell=2.0
Inc=0.200
Operator: TW
Version: 02B
File: 022688.E09

Uniroyal UNI-10K-S/N 510 O 1s Scan



PARAMETERS

Iter= 31

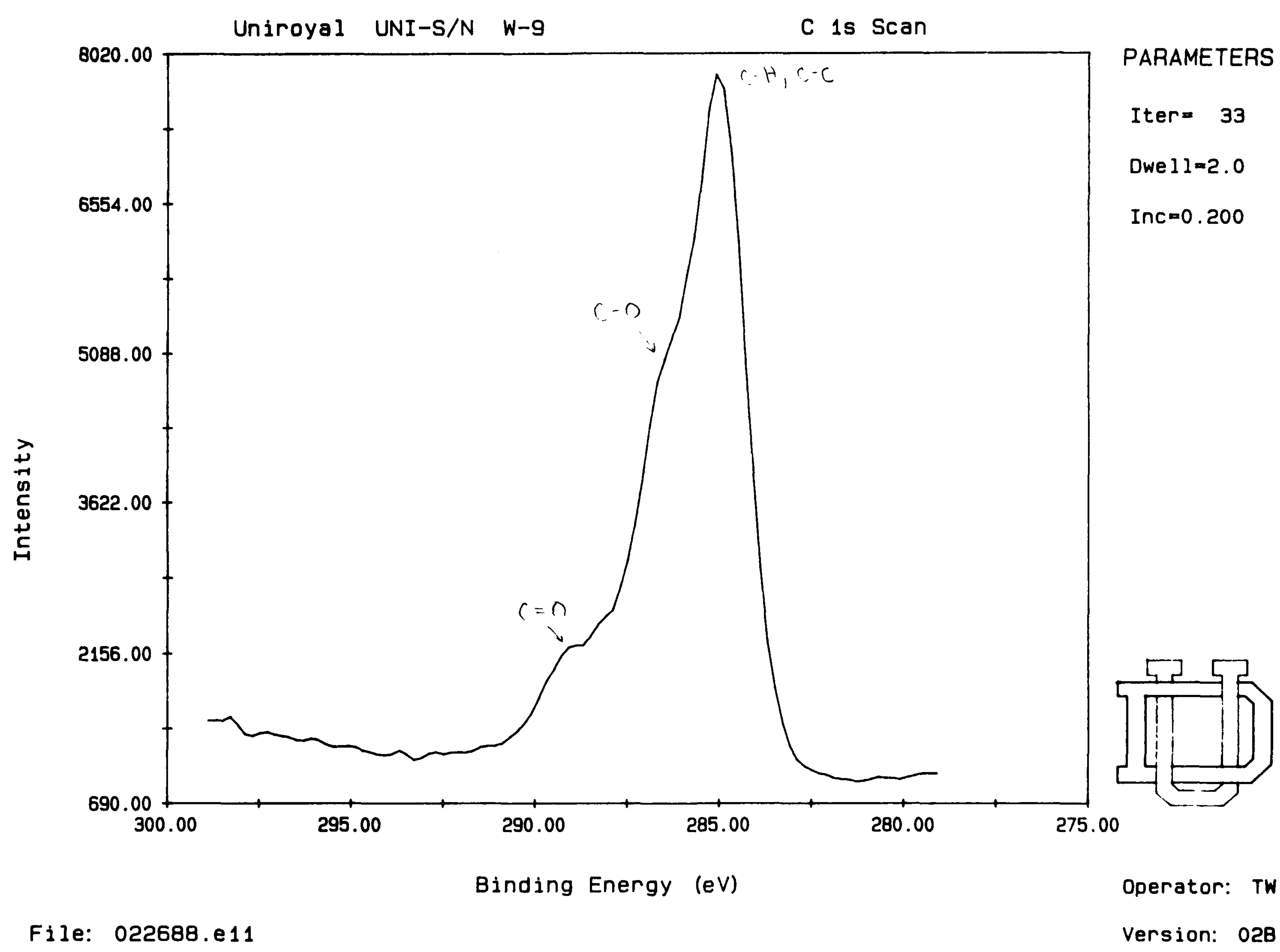
Dwell=2.0

Inc=0.200

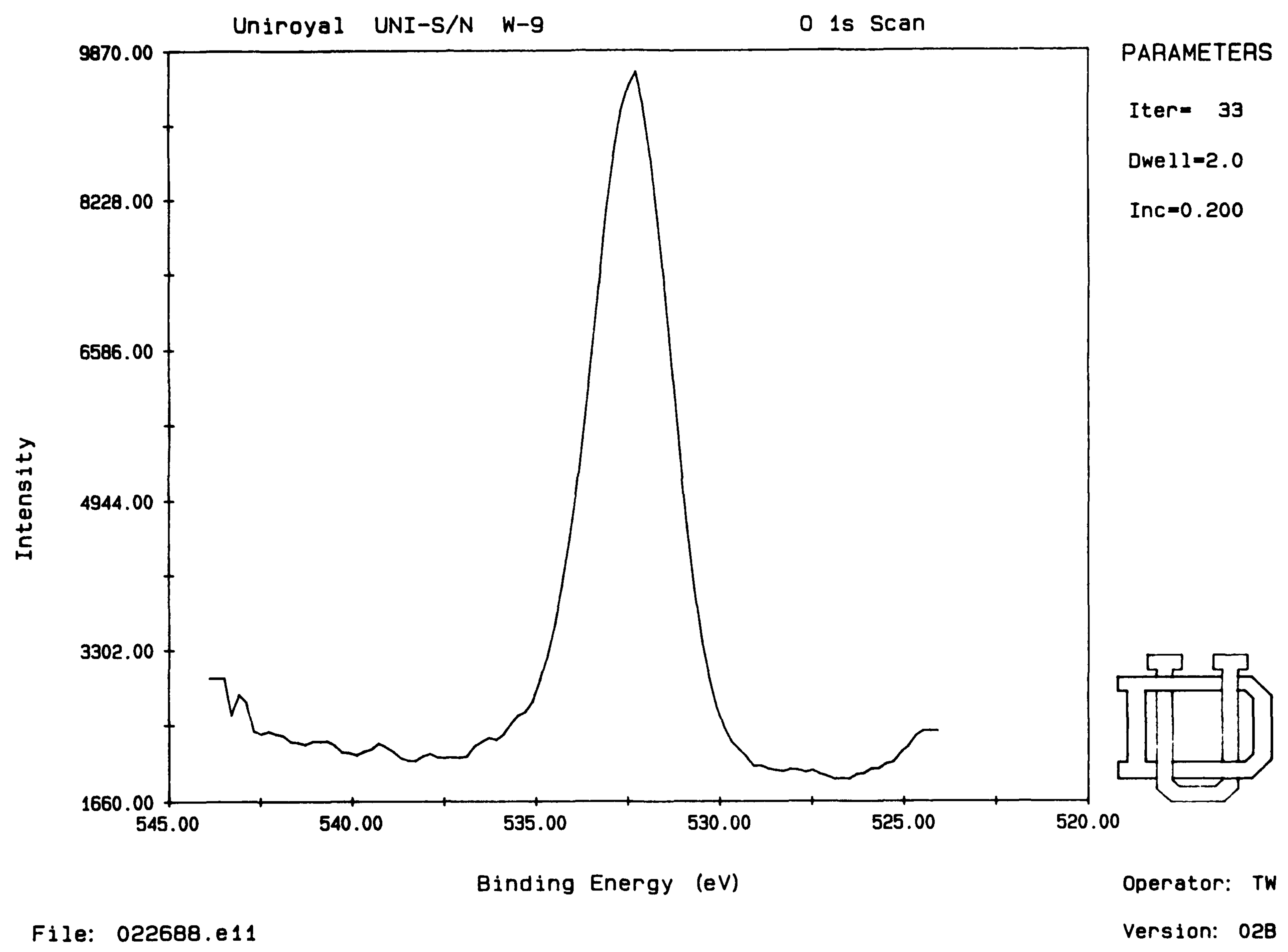
Operator: TW

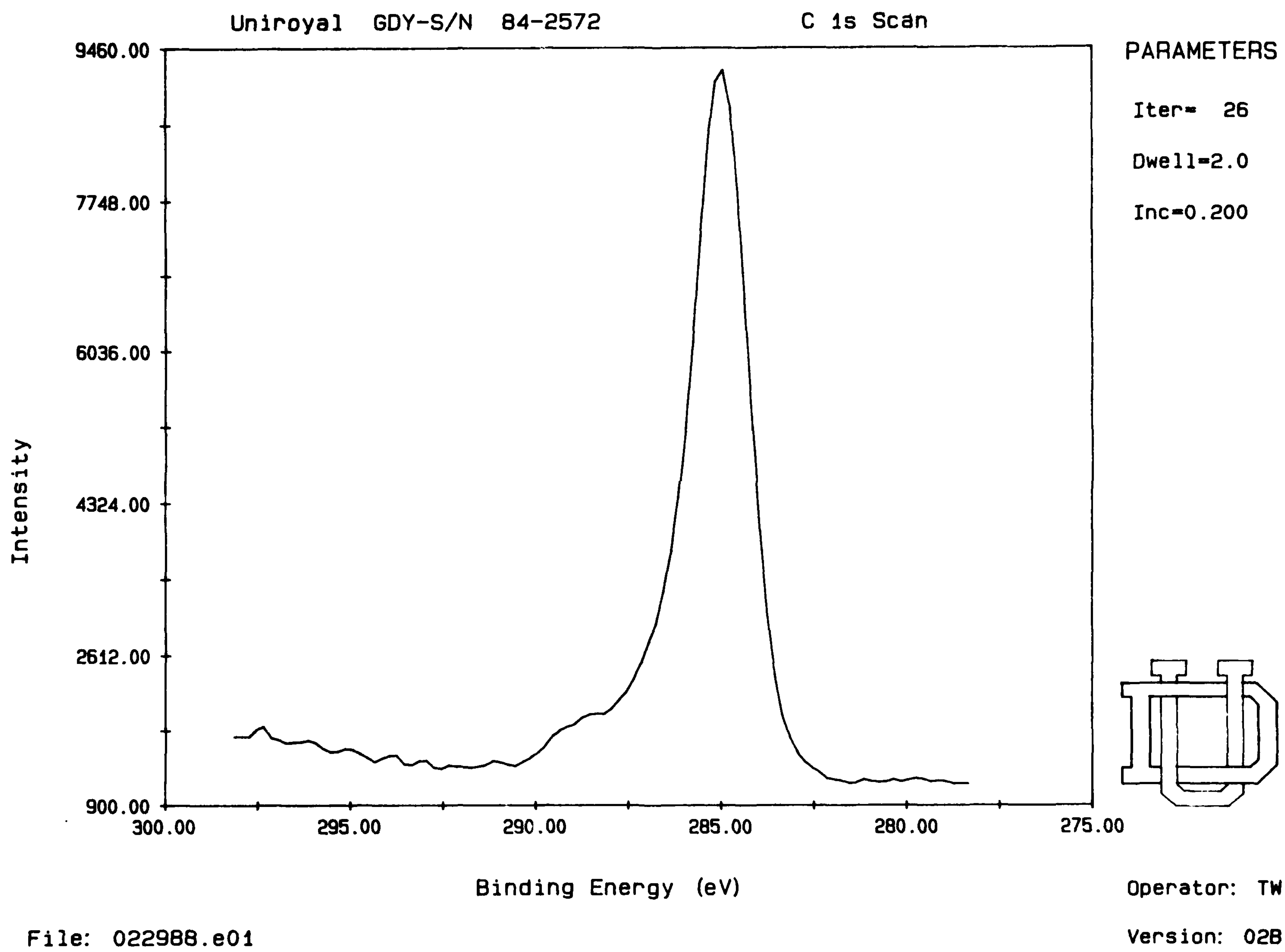
Version: 02B

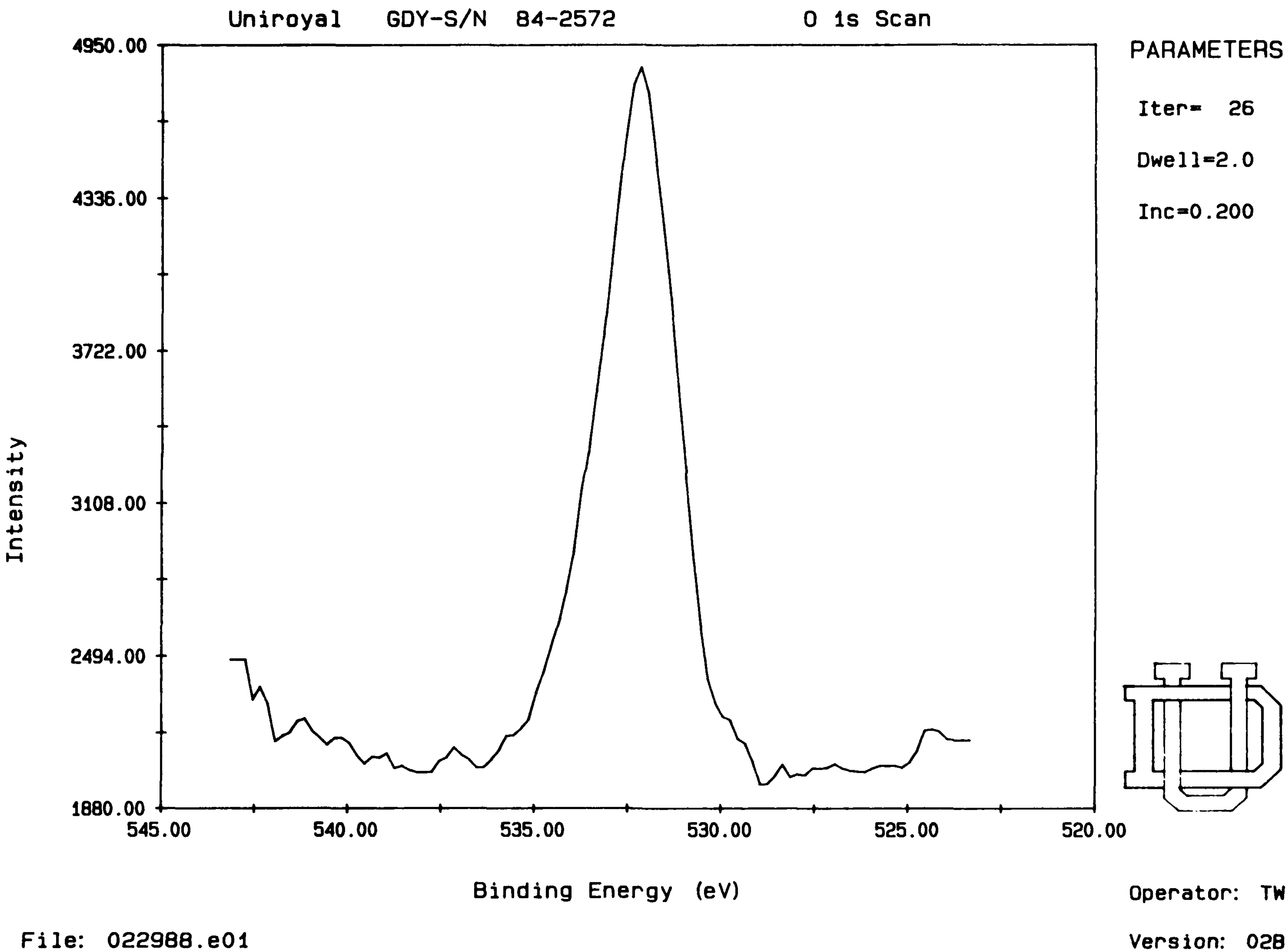
File: 022688.E09



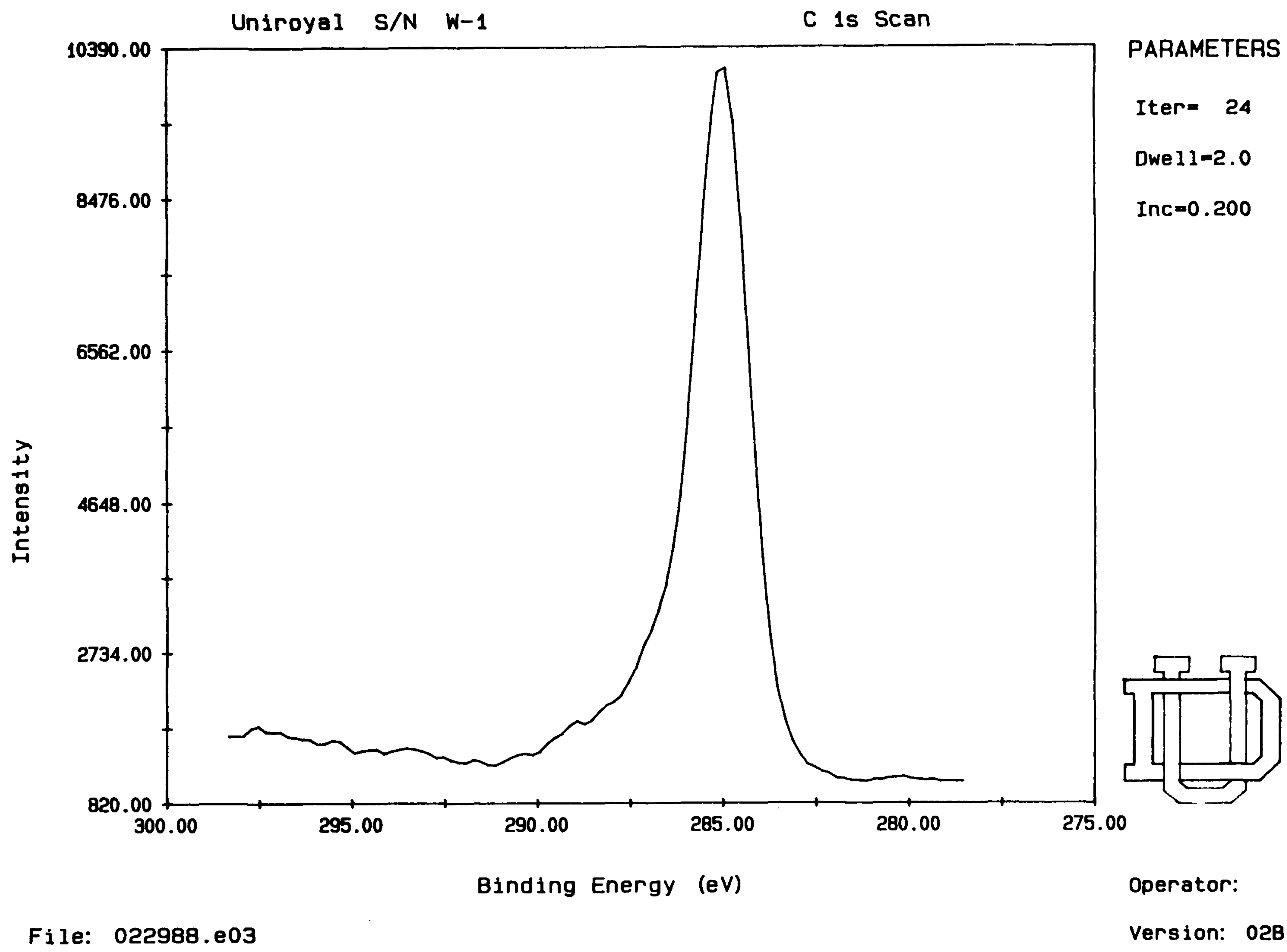
Uniroyal UNI-S/N W-9
C 1s Scan
PARAMETERS
Iter= 33
Dwell=2.0
Inc=0.200
Intensity
8020.00
6554.00
5088.00
3622.00
2156.00
690.00
300.00
295.00
290.00
285.00
280.00
275.00
Binding Energy (eV)
C-H, C-C
C-O
C=O
Operator: TW
Version: 02B
File: 022688.e11

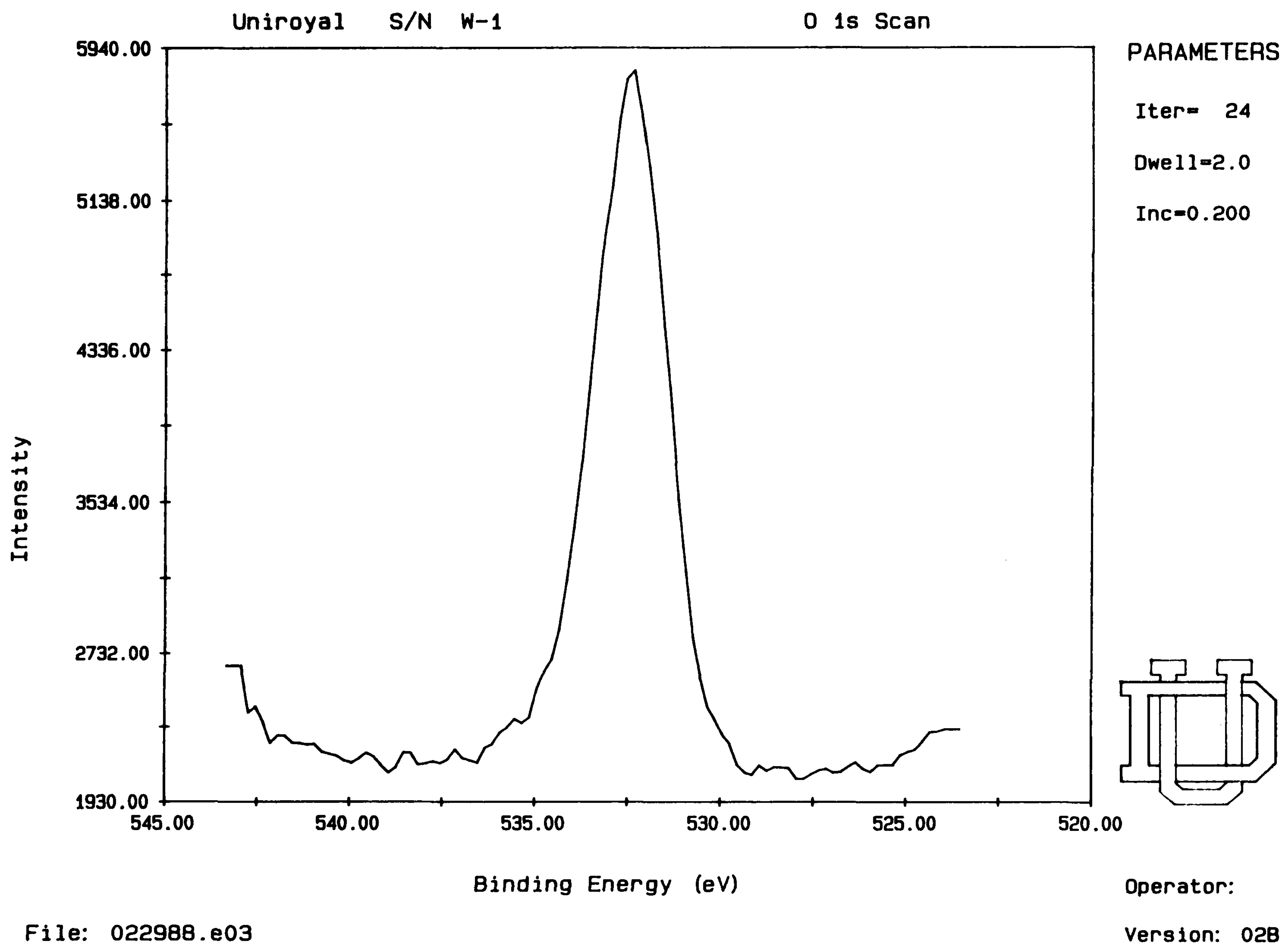

Uniroyal UNI-S/N W-9
O 1s Scan
PARAMETERS
Iter= 33
Dwell=2.0
Inc=0.200
9870.00
8228.00
6586.00
4944.00
3302.00
1660.00
Intensity
545.00
540.00
535.00
530.00
525.00
520.00
Binding Energy (eV)
Operator: TW
Version: 02B
File: 022688.e11

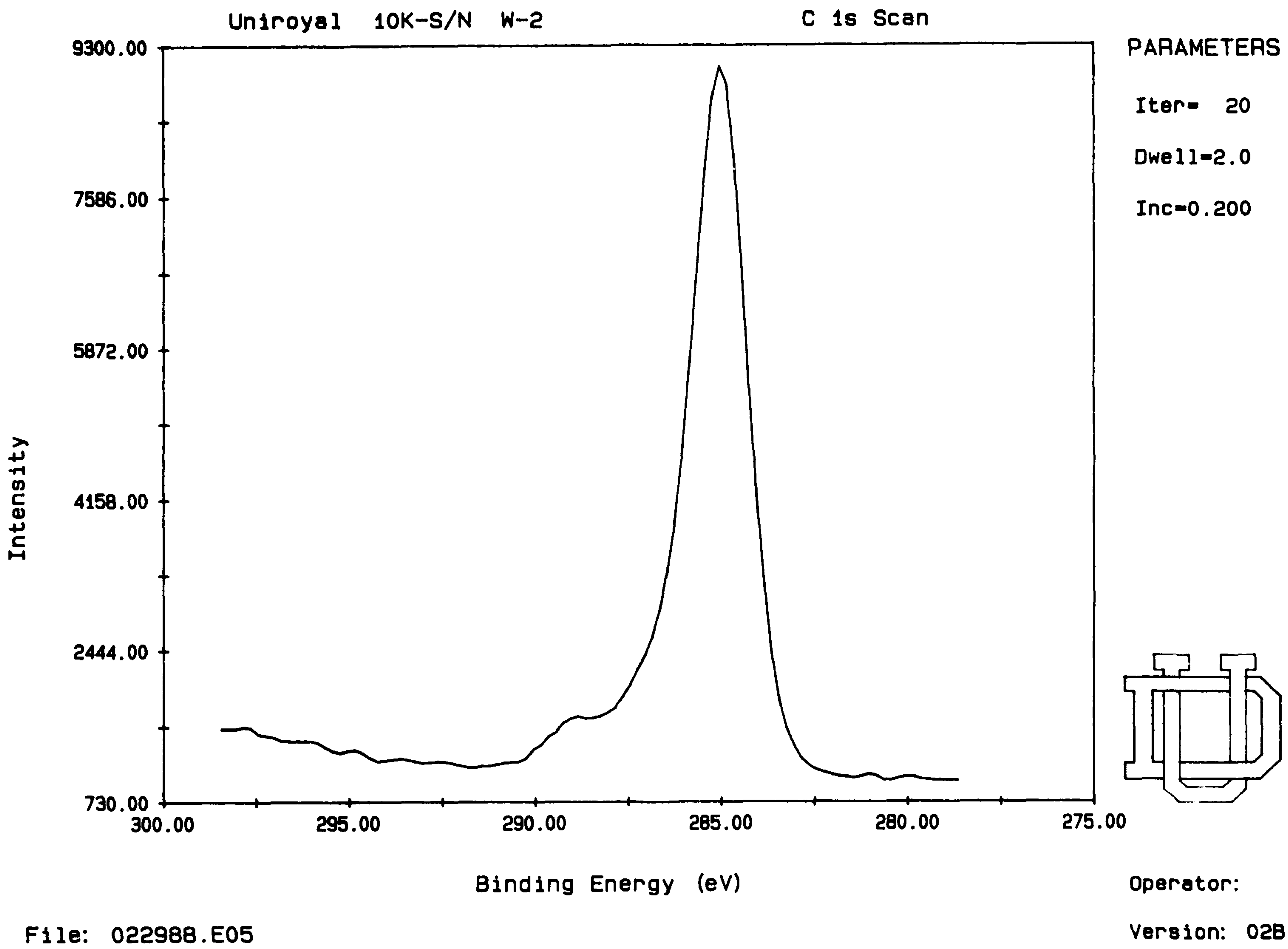

Uniroyal GDY-S/N 84-2572
C 1s Scan
PARAMETERS
Iter= 26
Dwell=2.0
Inc=0.200
9460.00
7748.00
6036.00
4324.00
2612.00
900.00
Intensity
300.00
295.00
290.00
285.00
280.00
275.00
Binding Energy (eV)
Operator: TW
Version: 02B
File: 022988.e01

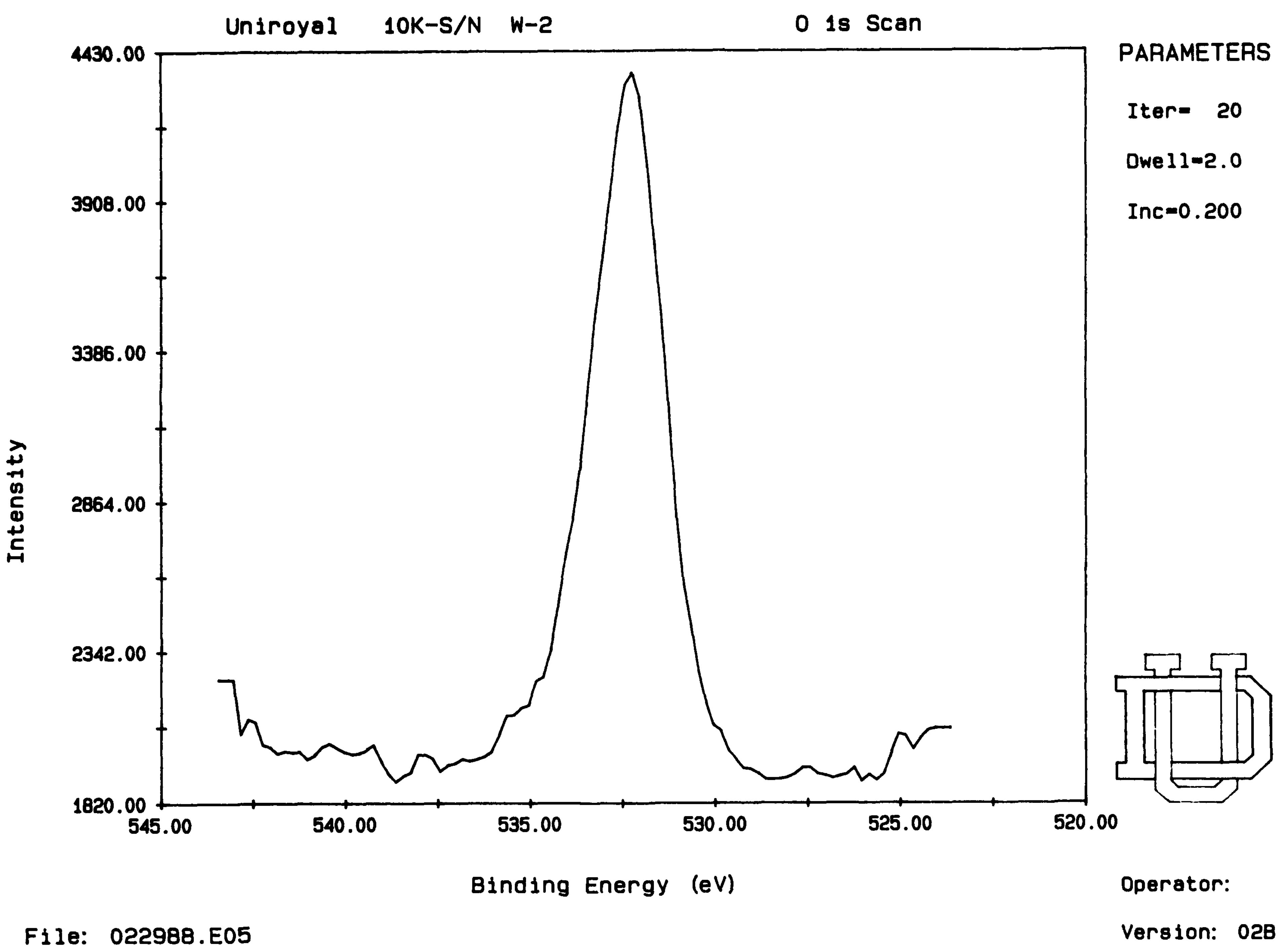


Uniroyal GDY-S/N 84-2572
O 1s Scan
4950.00
4336.00
3722.00
3108.00
2494.00
1880.00
Intensity
545.00
540.00
535.00
530.00
525.00
520.00
Binding Energy (eV)
PARAMETERS
Iter= 26
Dwell=2.0
Inc=0.200
Operator: TW
Version: 02B
File: 022988.e01


Uniroyal S/N W-1
C 1s Scan
PARAMETERS
Iter= 24
Dwell=2.0
Inc=0.200
Intensity
10390.00
8476.00
6562.00
4648.00
2734.00
820.00
300.00
295.00
290.00
285.00
280.00
275.00
Binding Energy (eV)
Operator:
Version: 02B
File: 022988.e03


Uniroyal S/N W-1
O 1s Scan
PARAMETERS
Iter= 24
Dwell=2.0
Inc=0.200
Intensity
5940.00
5138.00
4336.00
3534.00
2732.00
1930.00
545.00
540.00
535.00
530.00
525.00
520.00
Binding Energy (eV)
Operator:
Version: 02B
File: 022988.e03


Uniroyal 10K-S/N W-2
C 1s Scan
PARAMETERS
Iter= 20
Dwell=2.0
Inc=0.200
9300.00
7586.00
5872.00
4158.00
2444.00
730.00
Intensity
300.00
295.00
290.00
285.00
280.00
275.00
Binding Energy (eV)
Operator:
Version: 02B
File: 022988.E05


Uniroyal 10K-S/N W-2
O 1s Scan
PARAMETERS
Iter= 20
Dwell=2.0
Inc=0.200
Intensity
4430.00
3908.00
3386.00
2864.00
2342.00
1820.00
545.00
540.00
535.00
530.00
525.00
520.00
Binding Energy (eV)
Operator:
Version: 02B
File: 022988.E05